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CEREMONIAL STONES USED BY THE AUSTRALIAN ABORIGINES.

BY R. H. MATHEWS.

(*Read January 1, 1909.*)

The following is a short description of some remarkable stones used by the aborigines in certain areas scattered over the northwestern portion of New South Wales, which may be approximated roughly as lying north of 34 degrees south latitude and west of 148 degrees east longitude. The objects referred to have been observed by squatters and other residents of the bush in different places for many years past, but like most other matters connected with the aborigines, very little attention has been paid to them. They are occasionally found lying on the surface of the ground, or only partially exposed, on the flanks of sand-ridges, which may have been either old camps of the natives or places of their ceremonial gatherings. They have also been discovered below the surface, having probably been overlaid by drifting sand or soil, or were perhaps purposely hidden when not in use.

The scattered remnants of the tribes in the region indicated are all more or less civilized at the present time and have ceased to use these stones in their ceremonies, owing to the occupation of the district by Europeans for upwards of half a century. For this reason it is especially important that all available information should

be recorded and published as widely as possible, in order to bring these relics under the notice of every person who may have opportunities of obtaining further particulars regarding this interesting subject.

The stones in question vary in length from about six inches up to as much as two feet, but the more common lengths range from eight to fifteen inches. They are widest at the base, gradually decreasing in dimension towards the other end and terminating in a blunt point. They consist of different material, including sandstone, quartzite, clayslate, kaolin and such other kinds of stone as might be available.

For the present I shall describe only four of the specimens in my possession. One is a fine-grained piece of clayslate, which when found by the maker was probably very close to the requisite form and needed only a little trimming or grinding to bring it to its present shape. It is just a trifle under one foot in length by a maximum width at the base of two and four-fifth inches, by a thickness of one and a quarter inches. The weight is two pounds six ounces. It was found in the bush by Mr. E. J. Suttor, owner of Tankarooka Station, on the Darling River, near Tilpa, New South Wales.

I have prepared two diagrams exhibiting the two wide faces and the edge of the implement, together with a view of the extremity of the base and have numbered the figures from 1 to 12. One face of the stone is practically flat throughout its length, being rounded off towards the edges on either side. The opposite face is slightly convex.

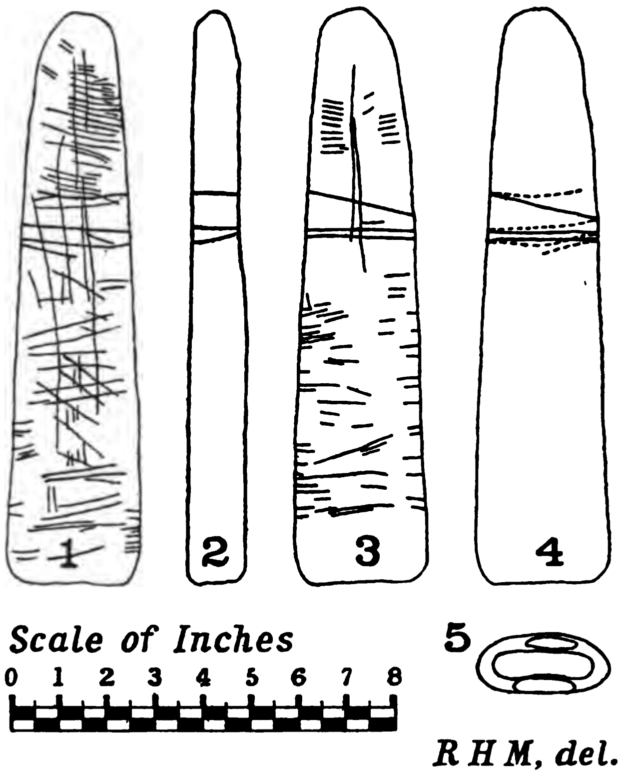
Fig. 1 delineates the flat face of the stone, which contains a large number of marks cut or scratched into the surface with some sharp instrument, such as a mussel shell, a sharp flake of hard stone, or a marsupial's tooth. Some of them are merely well-defined scratches, whilst others are cut into the stone about one-sixteenth of an inch. The marking extends from the base to the apex.

Fig. 2 shows one of the edges of the implement, the marks upon which are not reproduced, because they are continuations of those given on the two faces. I have, however, shown the position of three

principal incisions, which will be again referred to in dealing with Fig. 4.

Fig. 3 is the convex face of the stone, which contains about eighty marks similar in character to those of Fig. 1.

Fig. 4 has been introduced to exhibit the position of an irregular spiral incision which extends quite around the implement in a little over three folds. The firm black line on the diagram represents the cuts facing the observer; the dotted lines indicate their position on



FIGS. 1–5. Views of a Ceremonial Stone used by the Australian Aborigines.

the other side, if the stone were transparent. The position of the spiral on one of the edges of the stone is shown in Fig. 2. The commencement and end of the spiral appears on Fig. 1. It begins at three and seven-eighths of an inch from the apex and terminates at five and one-eighth inches.

A spiral of this kind has not been observed by me before and consequently adds to the value of the present specimen. In a few other cases, however, I have seen a single, continuous incised line girdling the upper half or pointed end of the stone. In most of the specimens in my possession, as well as in those which have come under my notice elsewhere, a girdling incision of any sort is absent. It is on this account that I have drawn attention to the peculiar marking of the stone now described.

Fig. 5 is a view of the basal end of the stone. A characteristic of all the stones of this class which I have seen consists in their having a saucer- or dish-shaped depression chipped or ground into the larger end. In our example there are three such depressions ground into the end of it. (See Fig. 5.) The two smaller ones are very shallow, although easily discernible, but the larger has a depth of nearly one-tenth of an inch in the center. The present is the only instance in which I have observed three of these depressions—one only being the general rule.

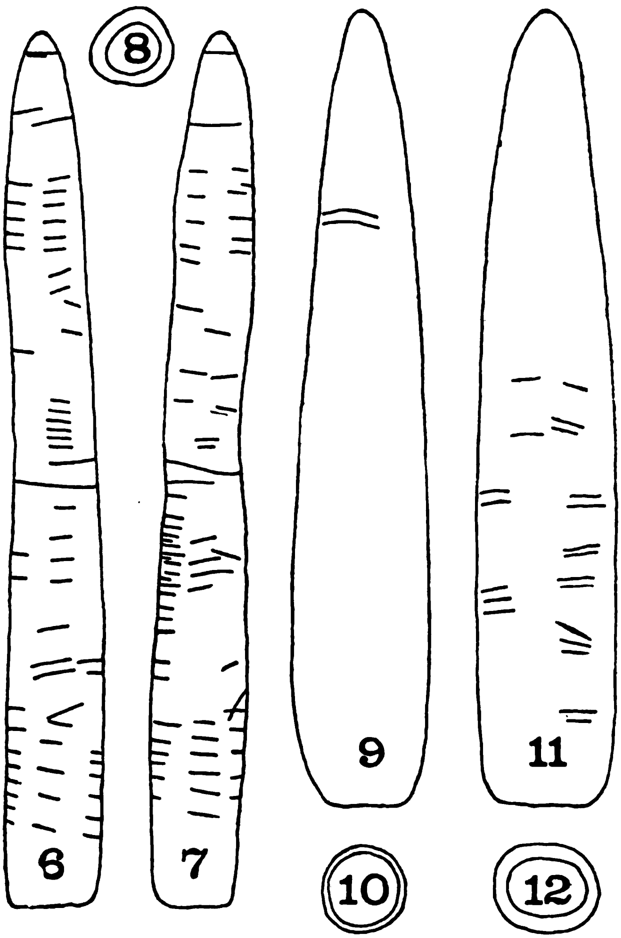
Another point to which attention may be invited is the very much elongated oval form of a section through the shaft. This is prominently seen in Fig. 5, where the diameter is more than twice as great in one direction as in the other. Most of the stones of this kind are nearly circular in section, whilst an elongated oval section is rarely met with. Again, very few of these stones are so profusely inscribed as the present example.

Fig. 6 is a long, thin, cylindrical spindle of a very hard clayslate, eighteen and a quarter inches long. At four inches from the base the greatest diameter is two inches, and at ten inches from the base (Fig. 7) the smallest diameter is one and eleven-twentieth inches. Fig. 7 represents the implement turned a quarter round.

A large amount of chipping and grinding has been done by the native artificer to bring this specimen into its present shape, especially at the pointed end and near the base. About the middle of the shaft the original surface of the stone is seen in a few patches some inches in length.

Commencing a little over an inch and a half from the base there are numerous incised marks, both horizontal and slightly oblique, all the way to the apex. About half an inch from the extreme point,

one of these incisions reaches all around the stone. At the middle of the shaft another line encircles it, but the two ends of the line, instead of meeting, overlap each other some two inches, and are from one-quarter to one-half inch apart. This encircling line is very faintly marked. There are about one hundred and forty well-



Figs. 6–12. Three Ceremonial Stones used by the Australian Aborigines.

defined incisions on the entire surface of this stone, one hundred and twenty of which are accurately reproduced in Figs. 6 and 7.

In addition to this number there are many other marks which, although distinguishable, are mere scratches and have evidently never been anything more. They are of the same character as the well-defined cuts, but much shorter.

Fig. 8 gives a view of the base of the stone, in which there is a saucer-like depression, the average diameter of which is nearly an inch and a quarter. This concavity has been made by picking the surface with some sharp instrument, such as a pointed flake of hard stone, the punctures being still plainly discernible. After the picking out was done the surface was rubbed or ground fairly smooth. The depth of the hollow formed in this way is a little more than one-twentieth of an inch. The specimen was found on Buckanbee Run, Darling River, and its weight is three pounds twelve ounces.

Fig. 9 is a soft sandstone, sixteen and one-half inches long, with a practically circular shaft, the greatest diameter of which is two and sixteen-twentieth inches, from which it evenly diminishes to a well-defined point. At four and one-quarter inches from the point there are two slightly curved parallel lines cut well into the stone. On the opposite side of the specimen are two similar incisions, which are not of course visible in my drawing. These comprise all the marks on this stone.

From the thickest part of the shaft to the base the diameter slightly decreases, until it averages a little over an inch and three quarters (Fig. 10). The diameter of the depression in the base averages nearly two inches and its depth is one-eighth of an inch. The stone was found on Kallara Station, Darling River, and weighs three pounds fourteen ounces.

Fig. 11 is another specimen of decomposed sandstone, sixteen and five-eighth inches in length. At the thickest part the diameter measures two and eighteen-twentieth inches, and a section through any part of the shaft would give an almost circular outline. On the face selected for illustration there are twenty-one incised lines, comprising triplets, pairs and single marks.

Fig. 12 represents the base, whose diameter varies from one and three-quarter inches to two and a quarter inches. The usual saucer-shaped concavity has a mean diameter of nearly an inch and a half

and its depth is one-twentieth of an inch. This specimen was discovered on a sand ridge on Maira Plain Station, about fifty miles southeast of Wilcannia, and weighs four pounds and a half.

A few remarks will now be made respecting the uses of these stones, information on this point being now difficult to obtain for the reasons stated in the beginning of this brochure. "Harry Perry," an old aboriginal of the Darling River, who died at Bourke about a year and a half ago, informed me that although he had never seen the stones in actual use himself, his father and other old men of the tribe had told him that they were employed in ceremonial observances connected with assembling of the tribe at the time the *nardoo* seed was ripe. The people would be invited to meet at a place adjacent to some low-lying ground which had been moistened by showers during the early spring months, or over which water had flowed in flood time, and which was consequently expected to produce large quantities of the *nardoo* plant. When the natives from the hinterland, in whose country there was little or no *nardoo,* came to the gathering at the appointed time they brought with them articles as presents or for barter with the people who had allowed them the privilege of feasting on the *nardoo* seed. My native informant believed that the stones in question were used in incantations for producing an abundant supply of *nardoo* and other seed bearing plants, as well as for an increase in game and fish. He also said that the messengers who were sent to gather the different portions of the tribe for these festivals, generally carried one of the incised stones to show the purpose of his mission.

As soon as other duties will permit I shall take pleasure in submitting to this Society a further article for publication, describing the various forms and materials of the interesting aboriginal relics briefly touched upon in the foregoing pages.

PARRAMATTA,
NEW SOUTH WALES, October 31, 1908.

THE EXPLORATION OF THE UPPER AIR BY MEANS OF KITES AND BALLOONS.

By WILLIAM R. BLAIR.

(*Read March 5, 1909.*)

Historical.

The kite, so far as we know, was first made and flown by the Chinese general, Han Sin, in the year 206 B. C. It was for a time used in war, being employed by the inhabitants of a besieged town to communicate with the outside, but later seemed to degenerate into a mere toy. Games in which kite strings are crossed and cut by the friction of one on the other are popular in China at the present time and great skill is shown in handling the small kites used for this purpose.

Professor William Wilson at Glasgow University and Benjamin Franklin at Philadelphia in the years 1749 and 1752 respectively were the first to use the kite in the study of upper air conditions. Wilson obtained temperatures at "great elevations" by means of self-registering thermometers, while Franklin used his kite as a collector of electricity.

Especial interest in upper air temperatures grew out of the consideration of the formula for refraction of light by the atmosphere, and kites carrying thermometers were again used in the years 1822 to 1827; this time by the Reverend George Fisher and Captain Sir William Edward Parry. At the same time upper and lower surface stations and captive balloons were first used for the purpose of obtaining temperatures aloft, the former by Sir Thomas Brisbane and the latter by the Earl of Minto. Readings were obtained at elevations of 400 feet with the kites and 1,340 feet with the captive balloons.

An editorial in the *Edinburgh Journal* for January, 1827, contains the following paragraph:

To those meteorologists who have sufficient leisure and the means of performing such experiments, we would recommend the use of kites and balloons for ascertaining the temperature and state of the upper atmosphere. The Earl of Minto has obtained several very interesting results by the use of balloons.

Ten years later, Espey, in our own country, used kites to prove his theory concerning cloud altitudes. He held that the base of a forming summer cloud should be as many times 100 yards high as the temperature of the air at the earth's surface is above the dew point in degrees Fahrenheit, *i. e.*, that these clouds form in ascending currents and that the air cools one degree Fahrenheit for every 100 yards it ascends. He was able to put his kite in the base of a cloud 1,200 yards above the earth's surface and not only proved his theory within the error of observation, but found that the motion of the kite in the base of the cloud showed ascending air currents. He also obtained some striking electric effects, wire being used instead of string to fly the kite.

The report of the Franklin Kite Club, about 1838, on the discovery of ascending air currents gave further proof of Espey's theory and stated that this theory had the recommendation of the American Philosophical Society.

A contemporary of Espey, James Swain, flew kites for the purpose of determining daily the height of that layer of "electrified air whose positive electricity was concentrated enough to expand the leaves of an electrometer." Swain used No. 30 steel wire, which he wound on a reel four feet in circumference and having a glass axle like the one used by the Franklin Club of Philadelphia. Steel wire is now universally used in kite flying.

In 1847 Admiral Back flew kites from the deck of his ship, *The Terror*, and obtained free air temperatures over the ocean.

Up to this time the kites used have been small and rather unstable in their flight. Little more was done with them until Archibald, an Englishman, began to look into the mechanics of kite flight in 1883. In the meantime mountain stations and captive balloons were further developed in an effort to get temperature readings at greater altitudes than had thus far been possible. An observatory was established at Mt. Washington in 1870 and one at Pike's Peak in

1873. The results obtained by these observatories showed, as was pointed out by Professor Abbe and others, that the readings were not sufficiently isolated from terrestrial influences, and attention was again turned to kites.

Archibald showed the value of vertical planes for steering purposes, constructed kites of greater lifting power and in 1887 used them to carry up a camera. Captain Baden Powell in England, interested in the possible use of kites in war, made them large enough to lift a man. Eddy, at Bayonne, N. J., in 1890, constructed a diamond kite in which the ends of the cross stick were bent back, thus introducing a vertical component in the planes which added to their stability in flight. In 1893, Hargrave, an Australian, invented the box or cellular kite. This kite, although of more complicated construction than forms heretofore used, very soon displaced them for every purpose and seems to contain the fundamental principle upon which all stable aëroplanes are constructed.

Eddy's work was taken up by Mr. Rotch and his assistants at Blue Hill near Boston, and Hargrave's by the U. S. Weather Bureau under the immediate direction of Messrs. Marvin and Potter. Marvin's study of the mechanics and equilibrium of kites led him to make some modifications in the original box pattern. The Marvin-Hargrave kite, at present quite widely used, is not only more efficient, but is stronger and, for meteorological uses, more convenient in details of construction than the Hargrave. About this time Marvin designed a meteorograph and convenient hand reels for the wire which were used in a series of upper air observations made at seventeen different stations during the summer of 1898. In this series daily flights were attempted but only 44 per cent. of these attempts were successful, the failures being due to lack of wind or other adverse conditions. Of the 1,217 ascensions made, about 180 were a mile in height, while two were slightly over 8,000 feet. The observations made have been reduced and are published in Bulletin F of the U. S. Weather Bureau.

Nearly all first rate weather services now have one or more upper air observatories. Our own upper air work has been concentrated at Mt. Weather, Va., under the immediate direction of the writer, where, since the first of July, 1907, daily except Sunday, ascensions

have been made with either kites or captive balloons, the latter being used only when the wind is insufficient to support the kites, or about one day in twenty. The apparatus in use at Mt. Weather is still undergoing improvement. The mean height at which daily (except Sunday) temperature and other observations are obtained is approximately 3,000 meters, or about 2 miles, above sea level. The highest altitude so far attained by means of kites is 7,044 meters, about 4⅜ miles. This flight was made at Mt. Weather on October 3, 1907. Flights closely approximating this in height were made at the same observatory on April 14 and September 30, 1908, while the fourth highest record, 6,430 meters, was made by the German Observatory at Lindenburg in November, 1905.

In the same year that Hargrave invented his kite, Charles Renard suggested the use by meteorolgists of small free balloons made of paper or other suitable material and having sufficient lifting power to carry up self-recording instruments. A balloon of this sort partially inflated with hydrogen at the earth's surface rises until the gas expands sufficiently to burst it, and the instrument is let down safely from this point by means of a small parachute.

Teisserenc de Bort, at his observatory at Trappes, Paris, and from the decks of ocean steamers, has obtained upper air records of great importance to meteorology with these paper balloons as well as with kites. More recently Assmann introduced india-rubber balloons about six feet in diameter. These are now the more generally used.

Preparatory to an ascension, this balloon is filled until the rubber begins to stretch, *i. e.*, from 3.5 to 4 cubic meters, depending on the weight it is to carry. The instrument is suspended from a small parachute thrown over the balloon, space being provided for the expansion of the latter to two or three times its diameter or to about twenty times the volume it had at the earth's surface. Sometimes two balloons are used, one of which bursts—the other lets the instrument down slowly. Records of temperature and humidity have been obtained at altitudes of 25,000 meters, over 15 miles above sea level with sounding balloons.

At present about twenty-five observatories—two in this continent, one in India, the others in Europe—are coöperating with the

International Commission for Scientific Aëronautics, using either kites or sounding balloons, or both. Captive and manned free balloons are occasionally used. Of these observatories, the universities of Manchester and Kasan each maintain one.

Apparatus and Methods.

The site chosen for an upper air observatory is to some extent determined by the kind of work to be done. A kite field should be clear of trees and other obstructions that might either entangle the wire or hinder the movements of the men who manipulate the kites. It should be situated on an eminence just high enough to prevent its being sheltered by any other in the immediate vicinity, but not high enough to introduce the complications of mountain and valley effects, unless indeed such local effects and not the general conditions obtaining in storms as they pass, be the object of the study. It is well if the country for thirty miles around in the vicinity of the field be free from large bodies of water and inhabited, for kites break away at times and these conditions facilitate their return. Close proximity to a city, on the other hand, is likely to bring kite flyers into unpleasant relationships with the local telephone and other electric companies who transmit power on overhead wires.

For captive balloons the conditions should be the same as for kites. Sounding balloons may be started from any place at which the true surface conditions can be recorded for comparison with the upper air data, except that the land area immediately to the east should be free from large lakes and fairly well settled. The balloons set free in this country by Professor Rotch have invariably traveled in an easterly direction and landed within a radius of 300 miles from their starting point. Each balloon carries with it instructions to its finder for packing and shipping and informs him that he will be rewarded for his trouble. This plan has brought back about 95 per cent. of all sounding balloons liberated in St. Louis, the only place in our country so far chosen for this work.

The ideal upper air observatory is one at which all three of these methods may be used, kites and captive balloons being less expensive and more efficient for levels up to 3,000 or 4,000 meters, 2 or 3 miles, and sounding balloons for higher levels.

The self-recording instruments used in kite and sounding balloon work are numerous in variety. Many observatories have instruments made from special designs. All are built on essentially the same plan. A clockwork rotates a cylinder which is covered with either a sheet of paper ruled to scale or a sheet of smoked paper or aluminium. Upon this sheet the pens or points, as the case may be, connected with their respective elements, trace the conditions. Paper scales are the more convenient and are used when the temperatures to be recorded are not so low as to freeze the ink. The instruments are made as light as possible, aluminium being the metal used in the construction wherever it can be adapted. From 750 to 1,500 grams is the usual weight of an instrument, those for use in kites being more substantially built than those for use in balloons. The anemometer usually consists of a small aluminium pin wheel mechanically geared to the pen—some are electrically connected. The hair hygrometer is the only form yet available for self-recording purposes that is light enough. The temperature is measured with either a bimetallic element or a partially coiled tube containing toluene. The barometer is of the aneroid type. The order of accuracy of these instruments is not high. Difficulty is experienced in keeping the anemometer properly oriented while the kite is flying. The hair hygrometer, if kept in good condition, probably records within less than 5 per cent. of the correct value. Records of pressure are, in nearly all cases, correct to within 2 mm., in many to within 1 mm. The temperature may be relied upon to one degree Centigrade in the records obtained from most kite flights, to less in many. When used in sounding balloons at very great altitudes the absolute error in any element is of course greater than those mentioned. In this case no anemometer is used, the wind velocity being determined from observations on the drifting balloon with one or more theodolites.

The differences in the various instruments consist chiefly in the way of exposing the elements so as to best obtain true records of the conditions in the vicinity of the instrument. It is essential that the temperature element especially be properly ventilated and insulated. The method of ventilation is of course different in sounding balloon and kite instruments. The former, being carried by the

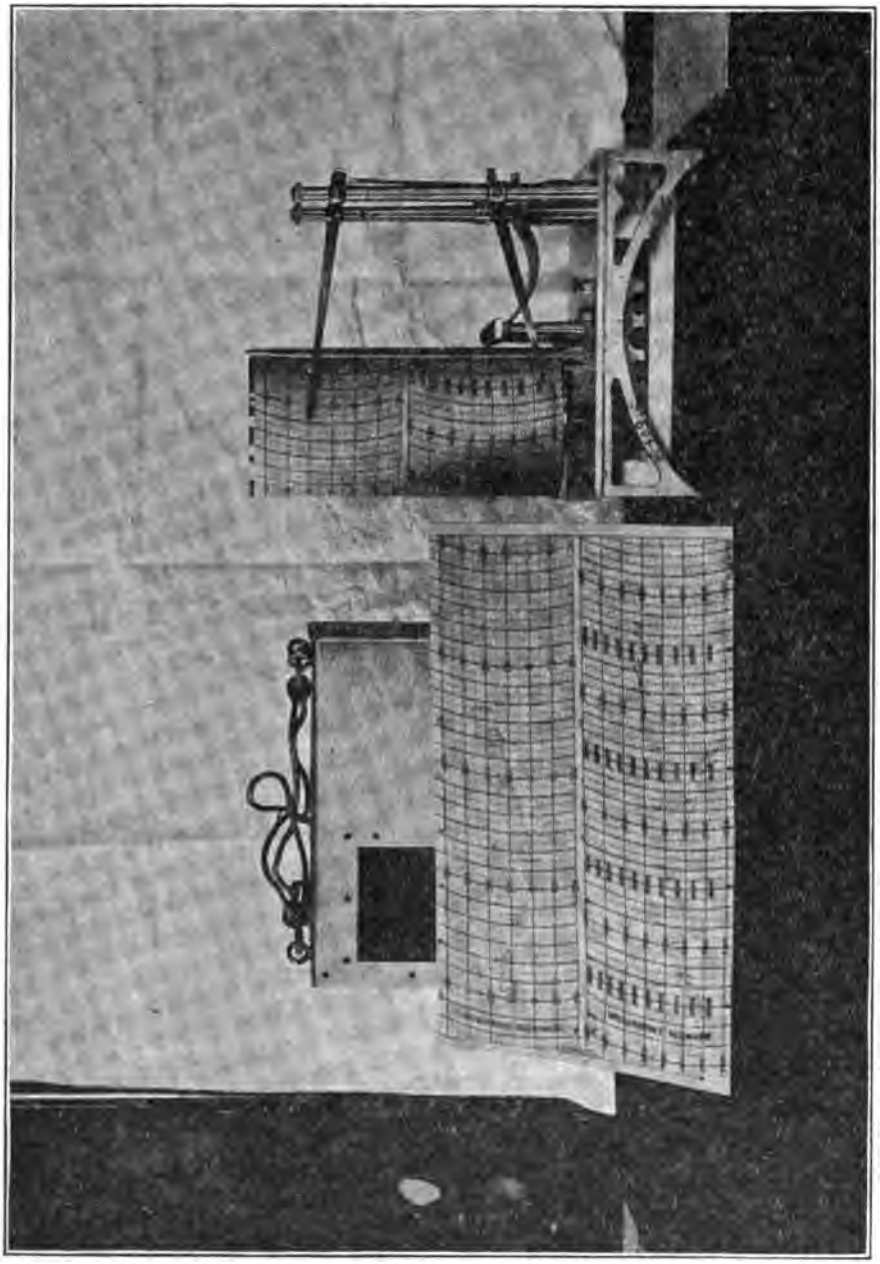


FIG. 1. Richard meteorograph.

wind, is in a calm except for its own upward motion through the air. It is therefore exposed in a vertical tube at the top of which is a funnel to insure the passage of a sufficient air current through the tube and about the element. The latter are held by the kites in the horizontal current in which the kite flies. The velocity of this current is always sufficient to keep the temperature element well ventilated so that care need be taken only to see that the element is in this current and screened from either the direct or reflected rays of the sun.

The meteorographs in use need comparison with standard instruments, at first to determine their scale values, frequently thereafter to guard against error due to slightly defective elements. Before and after an ascent the instrument is placed in a standard shelter with standardized instruments and allowed to record. Frequent readings of the latter are taken not only at these times but during the entire ascension. A base line for computation of altitudes is thus furnished, also a record of surface conditions for comparison with those of the upper air. To facilitate this computation and comparison, as well as to avoid errors due to the sluggishness of the elements, stops in the ascent and descent are made at frequent intervals. These stops need be for but a few minutes. Their times are recorded at the lower station and they are easily distinguishable on the traces. Of course it is impossible to make such stops with sounding balloons, and consequently instruments sent up by means of them should be, to some extent, at least, tested for sluggishness in addition to the tests made for scale values.

The cellular kite invented by Hargrave or some of its numerous modifications is the one most generally used for meteorological purposes. The Marvin-Hargrave kite, in which three planes are put in the front cell and the entire framework strengthened by fine steel wire braces, is the one in use at Mt. Weather. With slight modifications in the size and shape of the planes and in the proportion and distribution of lifting and steering surfaces, this kite has been made to serve in all winds from 3.5 to 22.5 meters per second. The dimensions of a medium-sized kite, one well adapted to carrying an instrument in winds of from 5 to 10 meters per second, are as follows:

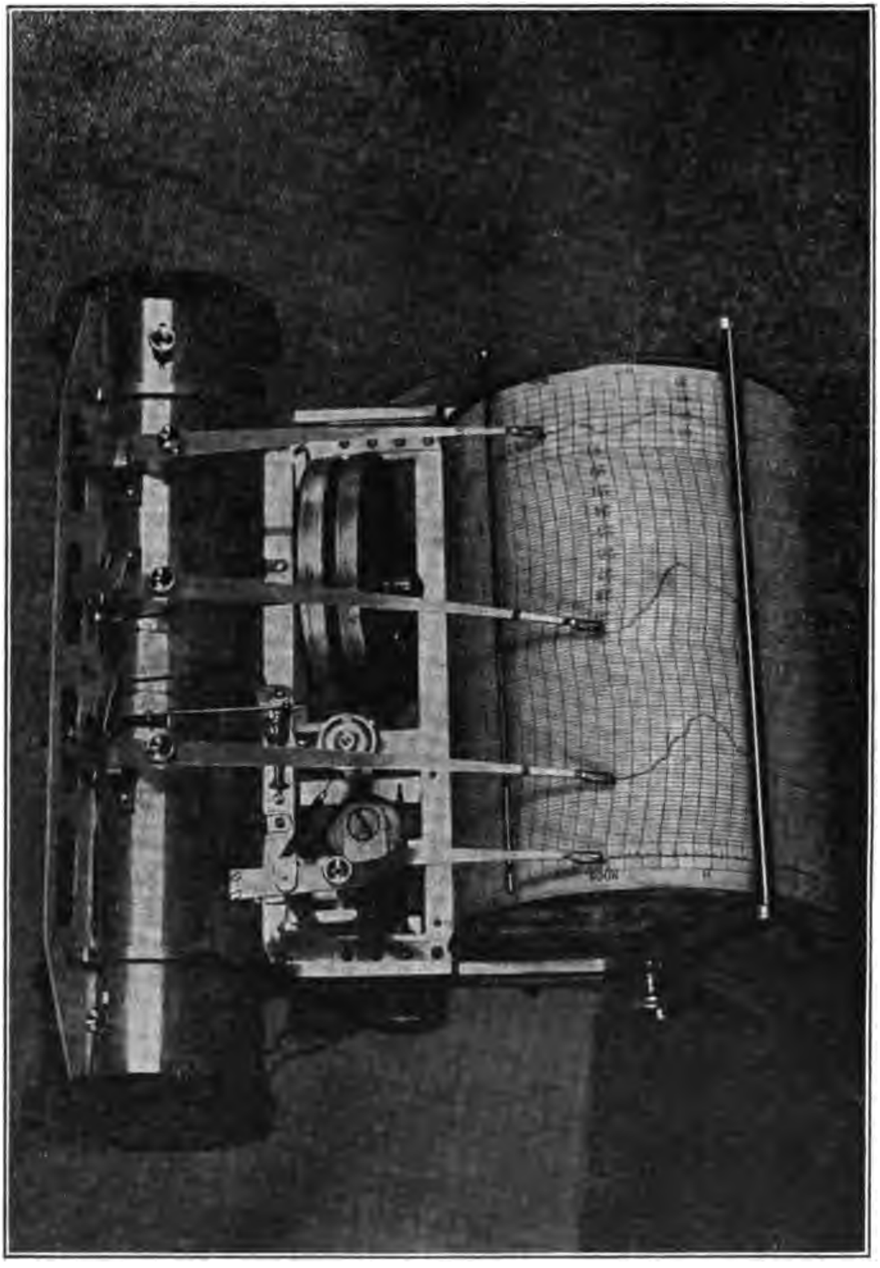


Fig. 2. Marvin meteorograph.

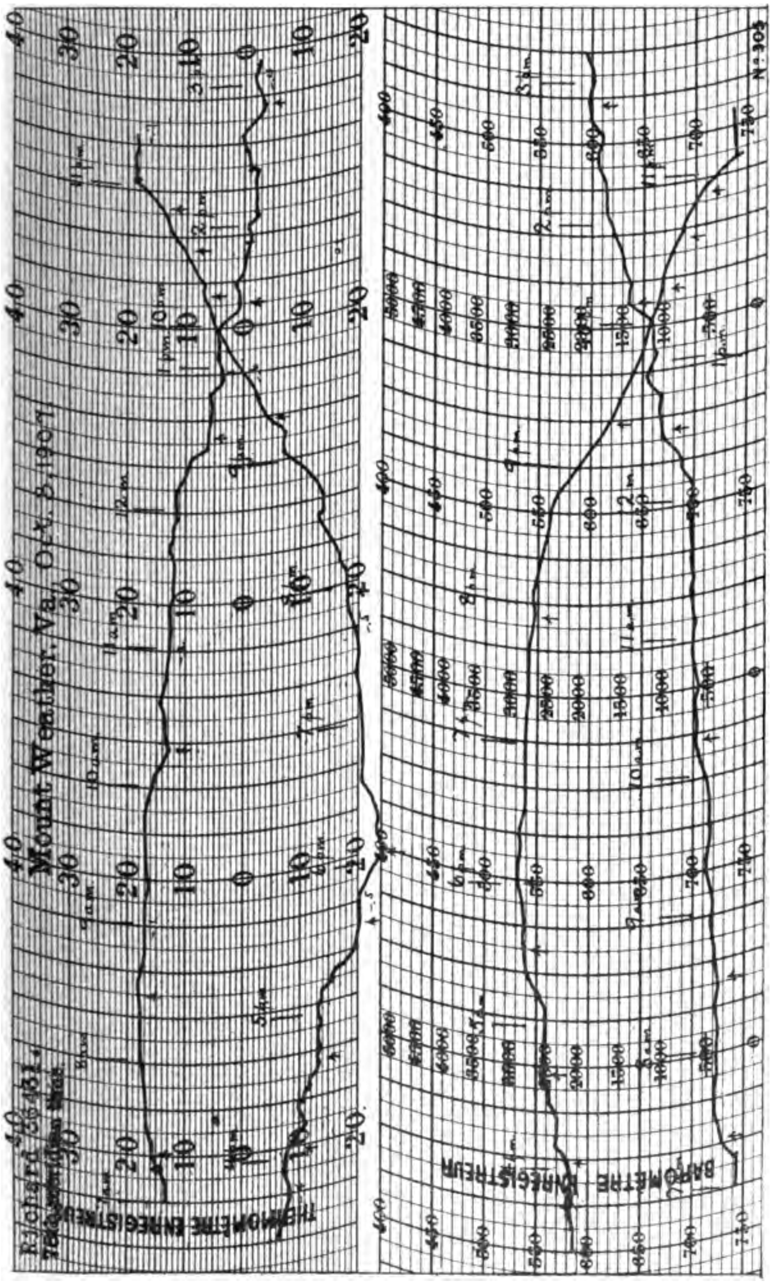


FIG. 3. Record from flight of October 3, 1907.

Height	204 cm.
Width	197 cm.
Depth	81 cm.
Width of planes	64 cm.
Plane space	76 cm.
Weight	3.2 to 3.8 kg.

There are five lifting planes, so called, and four steering. The area of the lifting planes is 6.3 square meters, while that of the steering planes is one third as much. Kites varying from these dimensions and necessarily therefore from these proportions are built for winds higher and lower than those to which the above-described kite is adapted. A type of kite which has flown in winds up to 22.5 meters per second has lifting planes aggregating 5.4 square meters in area. Its steering planes have half this area. It is a longer, narrower kite than the one whose dimensions are given above. A kite that has carried an instrument in winds as low as 3.5 meters per second has for the total area of its lifting planes 11.2 square meters.

The term lifting is not properly applied to any plane in the rear cell of a Hargrave kite, the function of that cell being more particularly steering. When a kite of the pattern described is sent up in a fog or low cloud in which the temperature is below freezing, ice crystals are found to attach themselves to the under side only of the three parallel planes in the front cell, but on both sides of all other planes in either cell, showing that practically all of the lifting is done by the front cell. A study of the formation of these crystals and the amount of ice deposited on different parts of a plane is very helpful in determining the most economic width and location of planes in a kite or other aëroplane.

At Mt. Weather we attach the meteorograph to the middle back rib of the first kite just behind the front cell. This insures it proper ventilation during the flight and adequate protection against injury in case the kite breaks away. Other, secondary, kites are attached to the line at intervals depending on the wind velocity and in numbers depending on the length of line put out. Their purpose is to support the wire. Twelve kites with a combined lifting plane area of 77.4 square meters is the greatest number we have ever used

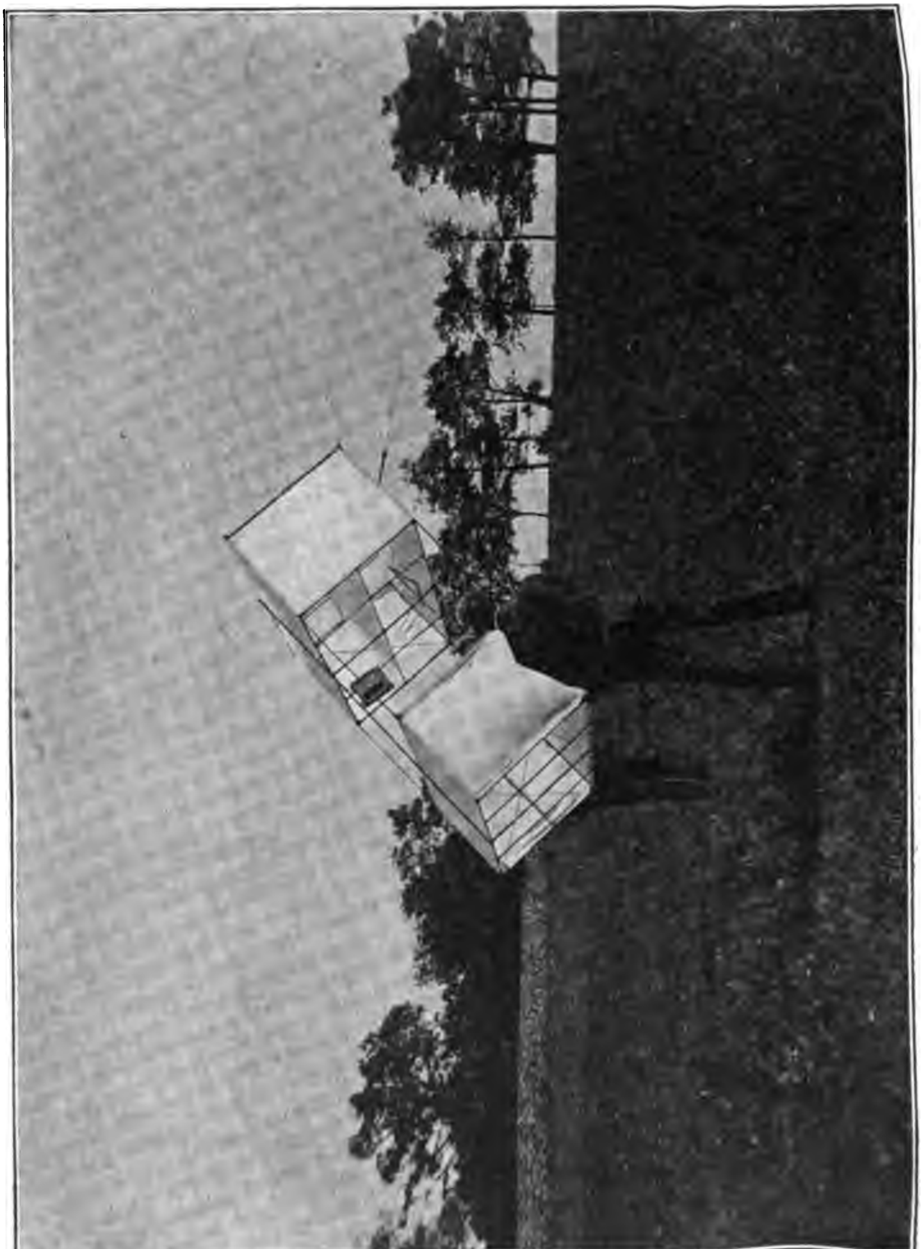


FIG. 4. Kite and instrument.

in making a flight. They carried a line 12,100 meters long. In our highest flight above referred to 11,735 meters of line was put out on nine kites.

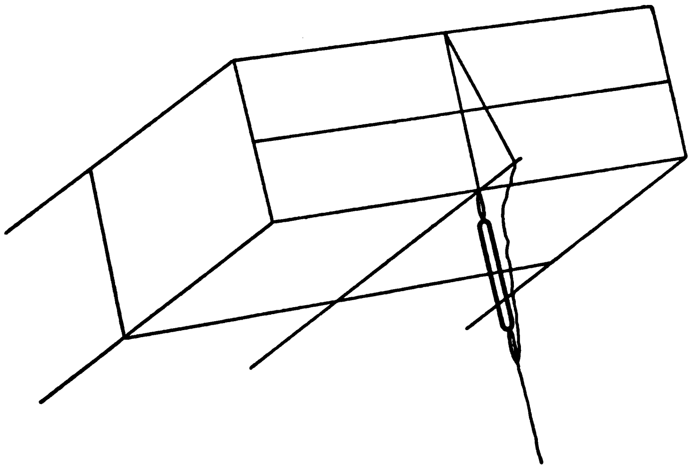


FIG. 5. Method of bridling kite.

The line is of piano wire made up about as follows:

Meters.	Inch in Diameter.
500	.026
500	.028
2,000	.032
3,000	.036
5,000	.040
5,000	.044

In all about ten miles of wire.

The reel is a very important part of the kite-flying apparatus. Its design should be such that the operator can easily control the rate at which wire goes out or comes in from 0 up to 4.5 meters per second. This enables him to keep his kites flying even if they are becalmed during flight, to throw them up through the calm strata of air which are often encountered, especially in the summer months, and, with the aid of a skilled field man, to start and land kites with little or no breakage. Our reel at Mt. Weather is equipped with a variable speed motor so geared to the drum that the wire may be brought in at any rate up to 2.7 meters per second.

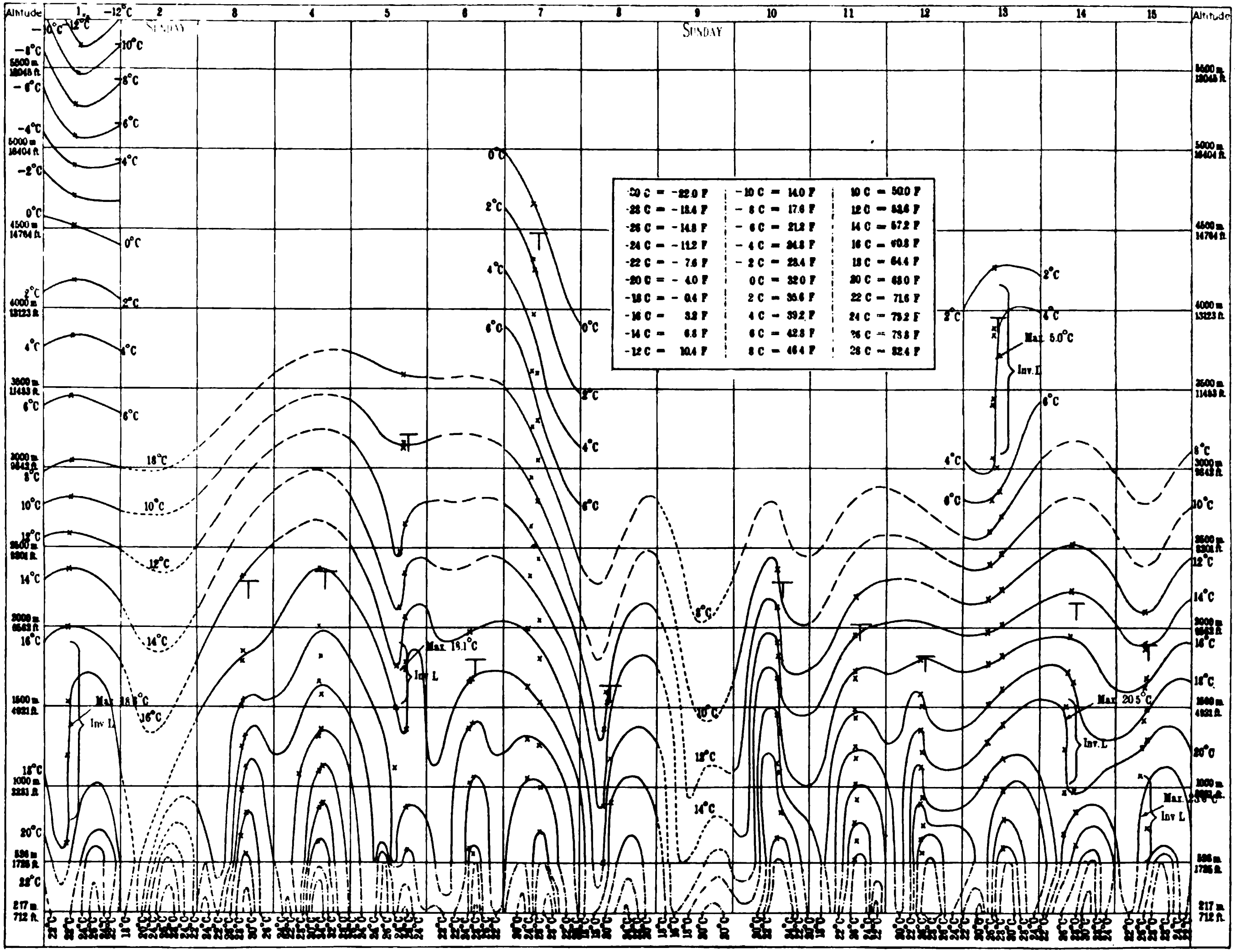


FIG. 6. Isothermal chart for August 1 to 15, 1908.

Too careful attention cannot be given to the condition of the reel preparatory to making a flight, and in general all apparatus must be well looked to. Failure in any one of the many details to be attended to at this time and during the flight is almost certain to result in some catastrophe. The field work has, for this reason, all the interest of our best college games and the man who is not equipped physically and mentally to enjoy such games will hardly enjoy or make a success of flying kites and balloons. The fact that for the past eighteen months no day (Sundays excepted) has passed in which one or more records of upper air conditions above Mt. Weather were not obtained speaks well for the spirit and efficiency of the men engaged in this work at that observatory.

The power plant at present in use is equipped with a 35 H.P. double cylinder gasoline engine, a 25 KW. dynamo, and an electrolyzer by means of which water is separated into oxygen and hydrogen, the latter for use in the captive balloons, and a gas compressor which may be used to compress hydrogen for shipment or to make liquid air with which to get sufficiently low temperatures to test sounding balloon instruments. A new combination steam power and heating plant is in process of building.

The computation of altitudes from the pressure trace of the meteorograph record by Laplace's formula and the evaluation of the other elements at these altitudes is another matter altogether and yet not devoid of interest. From five or six up to twenty or twenty-five levels are computed in each trace, *i. e.*, enough to show all peculiarities or changes in the temperature gradient or air currents, altitudes of clouds passed through, depth of cloud and fog layers and the highest points reached. From these data the temperature gradient, *i. e.*, the change of temperature with altitude, usually expressed in degrees centigrade per 100 meters, is plotted for each day and the upper air isotherms continuously charted. The whole, with more or less comment, is published quarterly in the Bulletin of the Mt. Weather Observatory. A study which has for its purpose the summarizing of the first year's data is still in progress. Valley stations are maintained on either side of the mountain. At these, data are collected for comparison with the surface readings obtained on Mt. Weather, 1,000 feet above them.

Five men besides the writer are engaged in the work of obtaining and reducing the records and in studying the resulting data. Duties are so arranged that these men take turns at outdoor as well as indoor work. In this way the work itself furnishes most of the physical recreation needed. None of the routine duties becomes especially irksome and the special lines of work are kept in better relation to each other and to the work as a whole than would be possible under another arrangement.

Concerning Data and Results.

The history of upper air work is, as we have seen, a brief one. The Hargrave kite and the sounding balloon are but fifteen years old, and with them began the study of the upper air as it is now carried on. This sort of investigation is comparatively new. The facts already—shall we say "aired"—have been made the subject of considerable comment. They themselves have so far had but little to say. They are cold and, among themselves, somewhat unsociable facts as yet, but we have become well enough acquainted with them to be certain that they with others yet to be "aired" or "unearthed" constitute a law-abiding community. "Unearthed" is used advisedly, for the energy liberated by the uranium deposits near the earth's surface may prove to be a considerable factor in the origin and development of disturbances occurring in the lower strata of the atmosphere. As a source of the energy displayed in the storms that continually pass over us, this factor has been considered by meteorologists as negligible compared with the energy received from the sun. The heating of the air from this latter source is due to the absorption by it of: (1) The direct rays of the sun, (2) the sun's rays which have been reflected from the earth's surface, and (3) the long heat waves radiated by the earth on account of its being heated by its absorption of the direct rays of the sun. Heat waves sent out by the earth due to other causes, such as radio-active minerals, would be operative in this third subdivision.

Water vapor absorbs the long heat waves readily and upon its vertical distribution in the atmosphere depends to a great extent the altitude at which their energy becomes effective in heating the air

and setting it in motion. Observations upon this distribution show that at 2,500 meters the moisture content of the air is one third what it is at sea level, at 5,000 meters one tenth. Most clouds of the cumulus and stratus types form below the latter level. It is to be expected, therefore, and we are not disappointed in finding, that this lower stratum of air is in continuous and complicated motion, vertical currents as well as horizontal obtaining. Above this stratum the air movement seems to be less complex.

When an air mass is heated to a temperature higher than that of the air about it, as we now see may be the case near the earth's surface, an unstable condition obtains and convection currents set in. A body of air rising to higher levels is cooled by its own expansion as it passes into the rarer atmosphere. This is called adiabatic cooling. If the body of air in question were dry, the rate of adiabatic cooling would be about one degree Centigrade per 100 meters, or one degree Fahrenheit per 180 feet. If it contain moisture, it will not cool so rapidly for the moisture in condensing gives off its latent heat into the air. This effect is a function of the relative humidity and tends to accelerate the upward motion and postpone the return of stable conditions. Sufficient condensation soon takes place, so that heat from this source ceases to offset the adiabatic cooling, and the convection current finds its upper limit. Other moist air coming in from below supports the system thus set up, and the whole moves with the upper westerly wind. This sort of circulation on a larger or smaller scale, more or less modified by other circulations of the same sort, is in progress continuously. An almost unmodified type of it may often be observed during the summer months in the formation of a single cumulus cloud. The cloud formation shows the outlines of the ascending air column. The horizontal air movement is slight at such times and the column nearly vertical.

We should expect to find then that the change of temperature with altitude is less in the lower moist stratum of the atmosphere than in that immediately above it and always, when mean conditions for a sufficiently long time, say a year, are considered, less than the adiabatic rate of cooling for dry air, some moisture being present at all altitudes. The sounding balloon observations in middle Europe,

MEAN TEMPERATURES AT DIFFERENT ELEVATIONS ABOVE MOUNT WEATHER, JANUARY AND JULY, 1908.

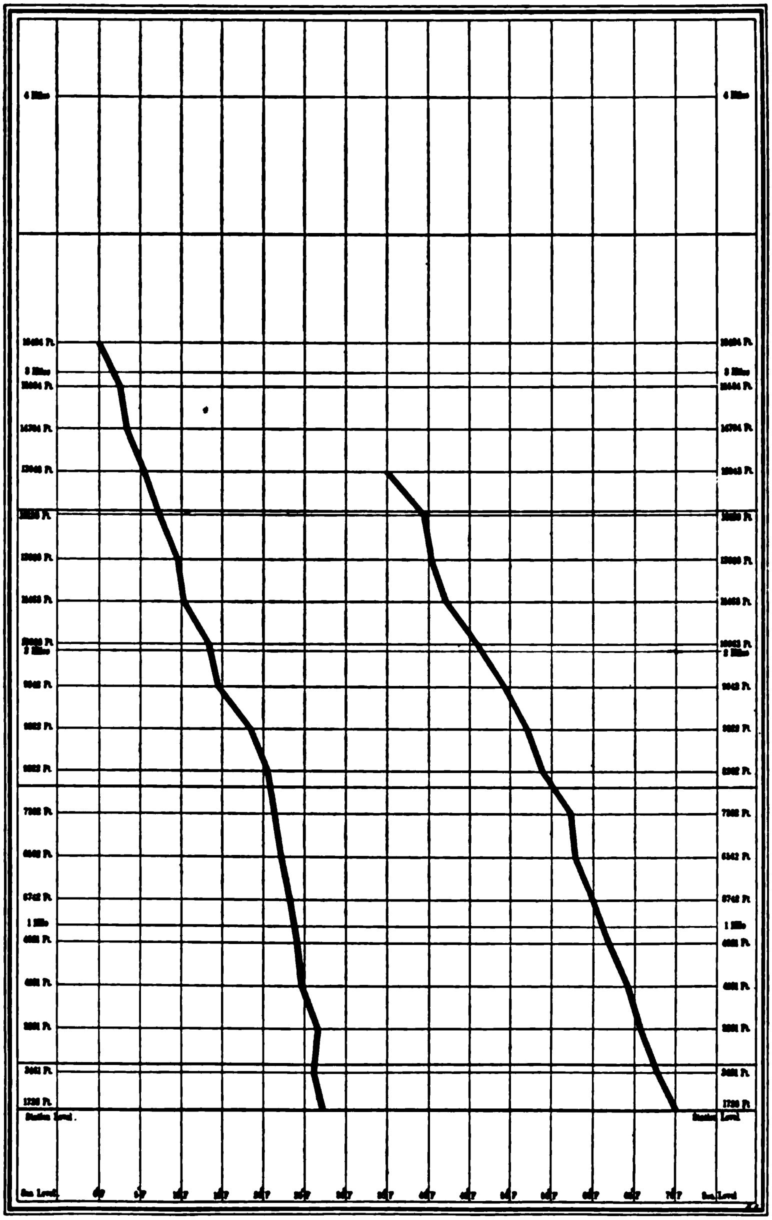


FIG. 7. Mean gradients for January and July, 1908.

as compiled by Hann, give the mean gradient up to 3,000 meters as .45 degree Centigrade per 100 meters, while at twice this altitude the temperature change is .70 degree Centigrade per 100 meters.

Within the moist stratum itself, observations on the relative humidity show that the yearly minimum at the earth's surface occurs in the summer months. The result is that condensation begins at higher levels in summer than in winter. The temperature gradient responds to these conditions, being greater nearer the earth's surface and less near the upper region of the moist stratum in summer than in winter. Values closely approximating the adiabatic rate are often found for the first 500 meters above sea level in the summer months. Comparison of the mean temperature gradients as observed in Europe and in this country, at Mt. Weather and Blue Hill, points to the fact that condensation takes place at lower levels in western Europe than here. This is reasonable when the comparatively dry surface conditons which obtain on our continent are taken into consideration.

It follows from the above that the moist or storm stratum is: (1) Deeper in summer than in winter, (2) deeper over a continent than over the ocean or smaller land areas. Convection currents are more sluggish where the relative humidity at the surface is low and therefore the barometric changes are less pronounced: (1) In summer than in winter, (2) in continental than in insular climatic conditions. Upon these considerations alone we should expect the deeper storms to be the less intense, but this is not in general true and another factor, viz., the velocity of the upper westerly winds, must be taken into consideration. By storm intensity is meant the suddenness of the changes brought about by the passage of the storm—probably best measured by the barometric changes.

These upper currents apparently control the rate of motion of the storms. Their velocities are found to vary with altitude, increasing up to heights of 10,000 or 12,000 meters. They also vary with the seasons. At an altitude of 3,000 to 5,000 meters their mean velocity for January is found to be fully one and a half times the mean for July. It follows that, for a given season, the deeper storms move faster, *i. e.*, continental and insular climatic conditions

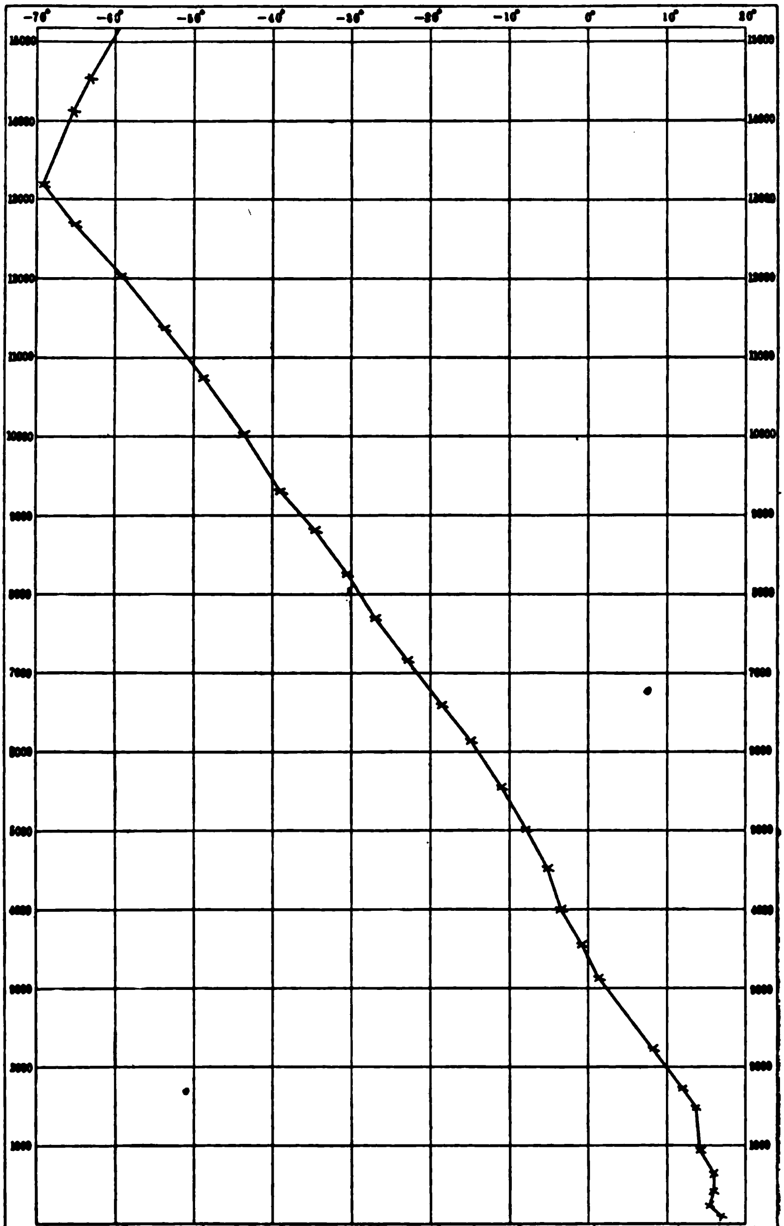


FIG. 8. Temperature gradient showing permanent inversion.

are respectively characterized by more and less rapidly moving storms. The effect of rapid motion upon a storm should be in general to intensify it, for, the more rapidly it moves, the greater the quantity of moist surface air that will be drawn up into it, and consequently the greater the amount of latent heat liberated because of the moisture condensation.

The conclusion is that, for a given location and season, the depth of a storm should indicate something of its rate of movement and consequently of its intensity. This is in accord with the experience at Mt. Weather.

It is said that American storms are more intense than those of Europe. If this be true, it is directly because of their more rapid motion and indirectly because of their greater depth.

Summer storms are less intense than those of winter. They are not only deeper but move less rapidly.

Cyclonic storm paths are, in general, found to pass through the regions of greater surface humidity. They seldom cross the arid or dry mountain regions, but travel along the great river basins, over the Great Lakes or along the gulf and ocean coasts.

So far the mean temperature change with altitude has been considered in two strata of the atmosphere: the lower, moist or storm stratum extending from sea level up to 4,000 or 5,000 meters, and the stratum above extending thence to 10,000 or 12,000 meters above sea level. In the first the mean temperature gradient is about .5 degree Centigrade per 100 meters, in the second about .7 degree Centigrade per 100 meters. The mean temperature at the top of the first stratum is about —10 degrees Centigrade, at the top of the second about —65 degrees Centigrade.

Above these strata still a third distinct stratum has been explored to an altitude of 25,000 meters above sea level. The striking peculiarity of this stratum is that in it the temperature increases from its base upward as far as it has been sounded. Its temperature gradient is small but negative. It was at first called the isothermal layer because the temperature seemed to change but little with altitude. Later observations, however, show a decided negative gradient or inversion of temperature and in consequence it is often called the upper or permanent inversion, the adjective being neces-

sary to distinguish it from temporary inversions frequently found in the lowest of the three strata described. The existence of the permanent inversion is a well established and interesting fact. Of the many balloons sent into it, only a few have been followed all the way up with the theodolite, consequently the wind velocities have been but little observed. The winds are found to be variable and of low velocity, 3.5 meters per second has been observed. This is in pronounced contrast to the prevailing west winds of extremely high velocity which characterize the layer just below it. Leading meteorologists still differ as to the explanation of this warm stratum. Their opinions may be found in the October 1, 1908, number of *Nature* in the form of a report of the discussion organized on this subject by the committee of Section A of the British Association.

Isothermal charts, such as the one for the first two weeks in August, 1908 (Fig. 6), illustrate the change in the upper air temperatures with the time. The daily rise and fall of temperature is seen to extend to about 1,500 meters above the surface. Superposed upon this and somewhat complicated by it is an aperiodic change which follows the passage of high and low barometer over the station. This sort of change extends up to the permanent inversion. Still a third change in temperatures aloft with time has an annual period. The time of greatest cold occurs near the earth's surface in January, at an altitude of 5,000 to 7,000 meters it comes in March and April, 7,000 to 9,000 meters in July, and 9,000 to 11,000 meters in September.

Means of temperature records from 581 balloon ascensions made by Teisserenc de Bort show that the greatest annual fluctuation in temperature occurs at an altitude of 6,000 meters above sea level, *i. e.,* about the base of the second stratum above mentioned. From this level up the annual fluctuation decreases gradually. Almost as great a change occurs at the base of the lower stratum, *i. e.,* near the earth's surface. In this layer the fluctuation reaches a minimum at an altitude of 3,000 meters. These facts compel us to set aside the idea not long ago prevalent that, at an altitude 7,000 to 9,000 meters above sea level, the temperature should be constant throughout the year.

Special interest attaches to the particular study of the peculiari-

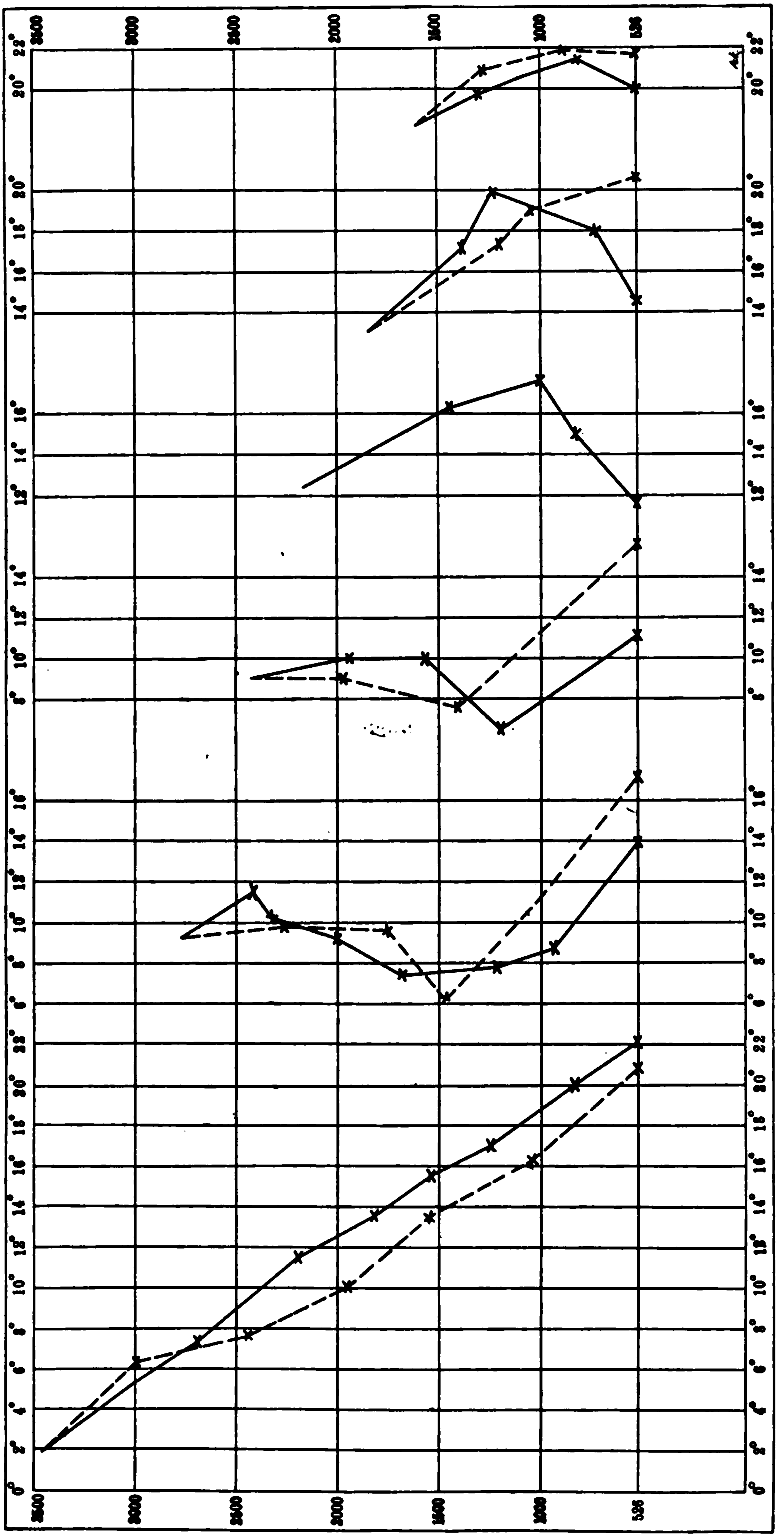


Fig. 9. The temperature inversion of September 15 to 19, 1908.

ties in the temperature gradient as recorded from day to day in the lower stratum, since these, together with the wind directions and velocities, must be relied upon for a knowledge of the air circula-

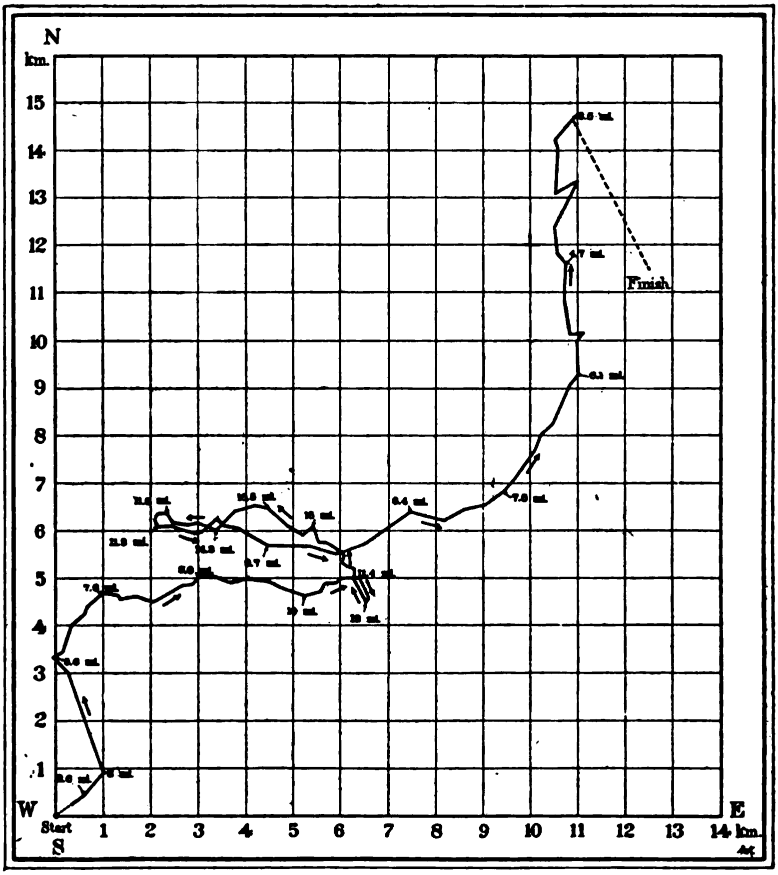


FIG. 10. Horizontal projection of path of a sounding balloon, Uccle, Belgium, July 25, 1907.

tion in particular storms as they pass. Among the most interesting of these peculiarities are the inversions. Fig. 9 shows a characteristic series beginning on September 15, 1908, and ending September 19, 1908. The advent of this inversion is preceded by a small temperature change with altitude at 2,900 meters on September 14.

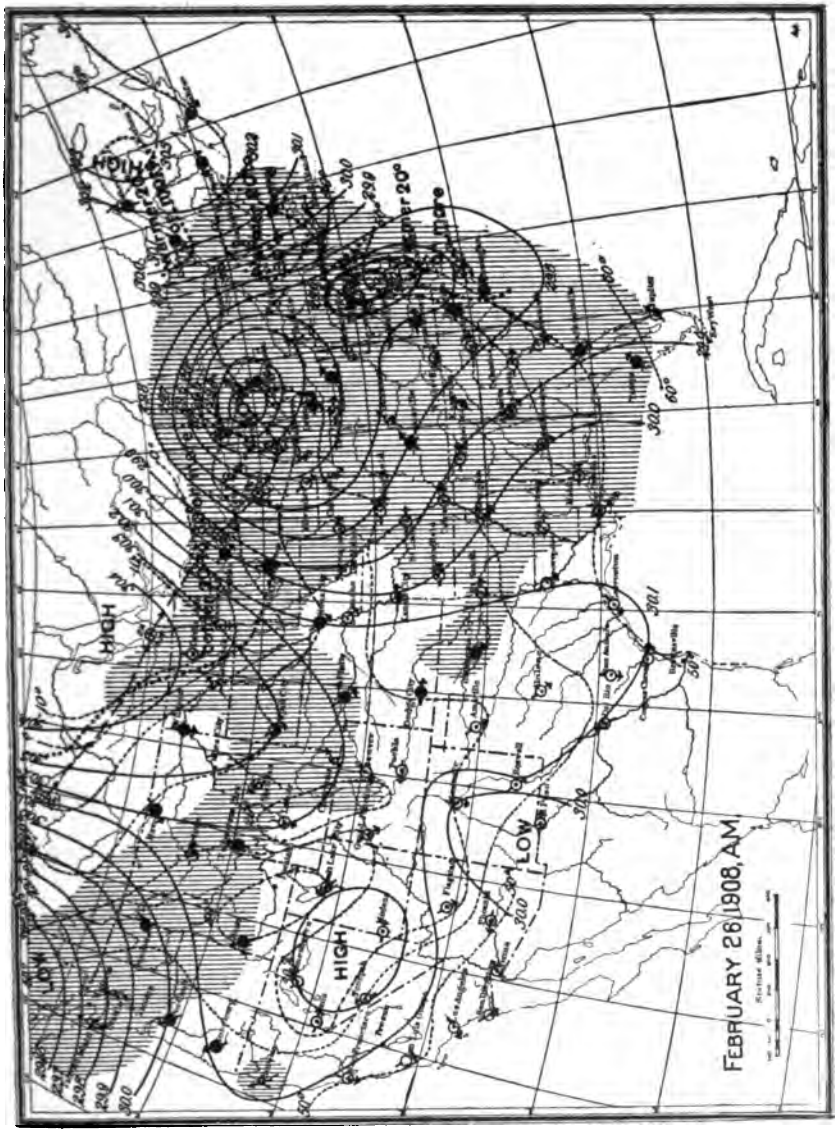


FIG. 11. Weather map of February 26, 1908.

During these five days an area of high pressure which was central over Vermont on the fifteenth moved southwestward over the observatory. The highest pressure in this area was 775.2 mm. on the morning of the fifteenth; this decreased to 765.0 mm. on the morning of the nineteenth. Under the influence of this area of high pressure, the surface wind was northeast on the fourteenth, southeast on the fifteenth and northwest during the remainder of the period. On the fourteenth and fifteenth the change in wind direction with altitude was counter-clockwise, while during the remainder of the period it was clockwise. The upper current in which the inversion occurred varied from north-northeast on the fifteenth to north-northwest on the nineteenth. These warmer northerly winds aloft are apparently due to an area of low pressure which was central about 300 kilometers east of the southern extremity of Florida at 8 a.m. on the fourteenth and moved north-northeast along the coast, reaching the Gulf of St. Lawrence at 8 a.m. on the nineteenth. This area of low pressure seems to have overhung the weak area of high pressure.

Fig. 10 shows the horizontal projection of the path of a sounding balloon. It illustrates not only the variability of the winds both as to direction and velocity with altitude, but the method of determining these elements when sounding balloons are used. Whatever the wind direction at the surface, the kites do not often go more than 3,000 meters high without coming into a wind with a strong westerly component. These changes in the wind, together with the temperature gradient, enable us to get the depth of a great many of the storms as they pass us.

Fig. 11 shows the map for February 26, 1908. The wind directions shown by the flight of this day were as follows:

Surface	NW.
1,000 meters	WNW.
2,000 meters	W.
3,000 meters	WSW.
4,000 meters	SW.

The peculiar arrangement of the two low pressure areas in the northeast is the interesting feature. The wind directions observed on this day during the kite flight show that the small or secondary low pressure area was only 2,000 meters deep. At this altitude the

kites swung into a W. to SW. wind appropriate to the circulation about the center of the primary low pressure area. The kite entered the circulation of the primary low at a lower level in the ascent than in the descent. This is shown both by the variation of the wind with altitude and by a slight inversion of temperature which occurred at an altitude of 1,768 meters in the ascent and at 2,600 meters in the descent. The secondary low is the center of a deepening storm, and its motion of translation becomes more rapid as its altitude increases. We find on the map for the next day that it has become the chief storm center.

Aside from this sort of study of the data obtained in the upper air work at Mt. Weather, the peculiar features of each day's record of conditions aloft are telegraphed to the Forecast Division in Washington at 8 p.m. They frequently prove of value in the making of the forecast. We have, however, but the one station at which the upper air is explored and, unless the disturbance with which the forecast for the day has chiefly to do is operating in our vicinity, we are unable to furnish much helpful information about it.

It happens sometimes that on a day when a flight of a certain height would be of especial interest, the winds are insufficient to carry the kites to the desired levels. The use of sounding balloons at Mt. Weather is inadvisable because of its proximity to the ocean. However, enough is being done to make the present work very much worth while, and to show us that the value of three or four stations at which both kites and balloons could be used would be inestimable in obtaining general as well as particular information of the storms as they pass. The latter, in the light of the former, should add to the accuracy of the forecast and perhaps extend the period for which a reasonable forecast may be made.

In this paper results based on upper air records of temperature, humidity, wind direction and velocity only have been touched upon. Kites and balloons furnish us the means of getting at electrical potentials and other electrical phenomena in the upper air, also may be the means of measuring the amount of insolation at different levels, all of which, as seen in the morning twilight time, promise to contribute much to the brightness of the day that is dawning in this field of applied physics.

WHY AMERICA SHOULD RE-EXPLORE WILKES LAND.

(PLATE I.)

BY EDWIN SWIFT BALCH.

(*Read April 22, 1909.*)

I.

In the year 1899 Sir Clements R. Markham, then president of the Royal Geographical Society, read a paper "The Antarctic Expeditions"[1] before the International Geographical Congress at Berlin. In this paper he mentioned the names and work of many Antarctic explorers, but he omitted the names of Wilkes and Palmer, and, in fact, he did not refer to any American. Moreover, he proposed to divide the Antarctic regions into four quadrants, all of which were to receive English names, and over the land which for fifty years has borne the name of "Wilkes Land," he intended to affix the term "Victoria Quadrant."

This remarkable attitude towards Americans, of a man holding such a prominent scientific position in England, arrested the attention of the writer, who began to study carefully Antarctic literature to find out on what Sir C. R. Markham based his opinions. It did not take long to become aware that although there were plenty of papers and some books of explorations about the South Pole, yet there was nothing in the shape of a connected history which was in the least accurate. Many things were omitted, and what was not forgotten was often wrong. A then recently published book "The Antarctic Regions," by Dr. Karl Fricker, teeming with errors and prejudice, was a shining example of this worthless method of writing geographical history.

That American explorers were thrown aside, was also evidently partly the fault of American writers. Wilkes was neglected, Palmer almost forgotten, and Pendleton entirely so, by their

[1] *The Geographical Journal*, 1899, Vol. XIV., pp. 473-481.

countrymen. Under these circumstances, why should others think of them? And yet America's record in the Antarctic is a brilliant one, indeeed the most brilliant of any nation!

It has taken the writer years of hard work, studying records and maps, and ransacking libraries and archives in America and Europe, to gradually work out the evolution of the discovery of the Antarctic regions. Beginning with a letter to *The Nation*[2] in answer to Sir C. R. Markham, following this with a long paper "Antarctica, a History of Antarctic Discovery,"[3] then again with a longer book "Antarctica,"[4] and another paper "Antarctica Addenda,"[5] it has proved necessary to supplement this with still another one, "Stonington Antarctic Explorers,"[6] and even yet the history is incomplete.

It soon became apparent, while working up the various records, that the nomenclature of the Antarctic regions was in a state of hopeless confusion. In many cases the names originally given by the discoverers had been superseded by names given by later travelers. Such was the case with the "Powell Islands" justly so called and so first charted after their discoverer, the English sealer George Powell, which was superseded by the meaningless name "The South Orkneys." The name "Palmer Land" wandered all over the map, according to the fancy of the map maker. The name "Graham Land," belonging to a small stretch of coast, was often applied to the whole *massif* of known lands in the western Antarctic. This arose from a curious cause. Graham Land lies some four degrees south of the Shetlands, and on Mercator charts, owing to the enormous relative increase in size for every degreee of latitude south, Graham Land swelled to inordinate dimensions, and the name was printed in giant letters, which pushed it into an unwarranted prominence.

The most curious thing of all was that there was no generic name by which to distinguish the lands which could be reached from South America, from those which could be reached from Australia.

[2] May 10, 1900.

[3] *Journal of the Franklin Institute,* 1901, Vol. CLI. and Vol. CLII.

[4] Philadelphia, Allen, Lane and Scott, 1902.

[5] *Journal of the Franklin Institute,* February, 1904.

[6] Not yet published.

"The lands lying south of South America" and "The lands lying south of Australia" were impossible titles to use in writing. It was necessary to invent something shorter, and in 1902, the writer proposed the names "West Antarctica" and "East Antarctica" to distinguish Antarctic lands in the western hemisphere from those in the eastern hemisphere, and first placed those names on a chart. Dr. Otto Nordenskjold, while wintering at Snow Hill, felt the necessity of such a nomenclature and invented independently the names "West Antarktis" and "East Antarktis," which on his return he decided, after reading the writer's "Antarctica," to change to "West Antarctica" and "East Antarctica."[7]

The name "West Antarctica" has already been placed on several maps, but apparently only attached to the South Shetlands, Palmer Land and Graham Land mass. Of course, "West Antarctica" should include all the lands in the western Antarctic, such as Coats Land and King Edward Land, just as "East Antarctica" should include all the lands in the eastern Antarctic, namely, Wilkes Land, Victoria Land, and Enderby Land.

Little by little, as the writer unearthed neglected printed records and manuscripts, a grand story of forgotten American enterprise and pluck was revealed. As far back as the year 1800, Captain Swain, of Nantucket, discovered in Antarctic waters a small island, which was reported afterwards as sighted by two other Americans, Captain Macy and Captain Gardner. In 1819–1820, Captain Sheffield and Mate N. B. Palmer reached the newly discovered South Shetlands on a sealing voyage. In 1820–1821, Captain Nathaniel B. Palmer discovered the coast of the northern mainland of West Antarctica, which was rightfully called Palmer Land. In 1821–1822, Captain N. B. Palmer sailed along this coast, and afterwards, in company with the English sealer Powell, discovered the Powell Islands. In 1822–1823, Benjamin Morrell sailed over part of the Antarctic Ocean, and sighted some of the coasts of West Antarctica, south and east of the Shetlands. Before 1828, Benjamin Pendleton sailed south and west from the Shetlands, and discovered the coast, afterwards called Graham Land, and the entrance of a great strait, doubtless Gerlache Strait. In 1830, Nathaniel B. Pal-

[7] "Antarctica or Two Years amongst the Ice of the South Pole," p. 69.

mer and Alexander S. Palmer explored a large section of the Antarctic Ocean, west of the Shetlands.

In 1839 and 1840, the United States Exploring Expedition, under the command of Lieutenant Charles Wilkes, U. S. N., made two voyages to the Antarctic. The first was in West Antarctica, to the Shetlands and along the coast of Palmer Land. The second was in East Antarctica. Starting from Australia, in January and February, 1840, Wilkes discovered the coast of East Antarctica and sailed along it for about 1500 miles. To this coast he gave the name of "The Antarctic Continent," but geographers have gradually and rightfully renamed it "Wilkes Land." While Wilkes did not see the whole coast of Antarctica, yet he saw enough to make it certain that there was a continental land mass at the South Pole. Geographers have hardly even yet, and Americans in general have certainly not, realized what a great discovery Wilkes made. There have been only three continents discovered since ancient times, America, Australia and Antarctica, and Americans ought to be proud that the discovery of the third was made by Americans.

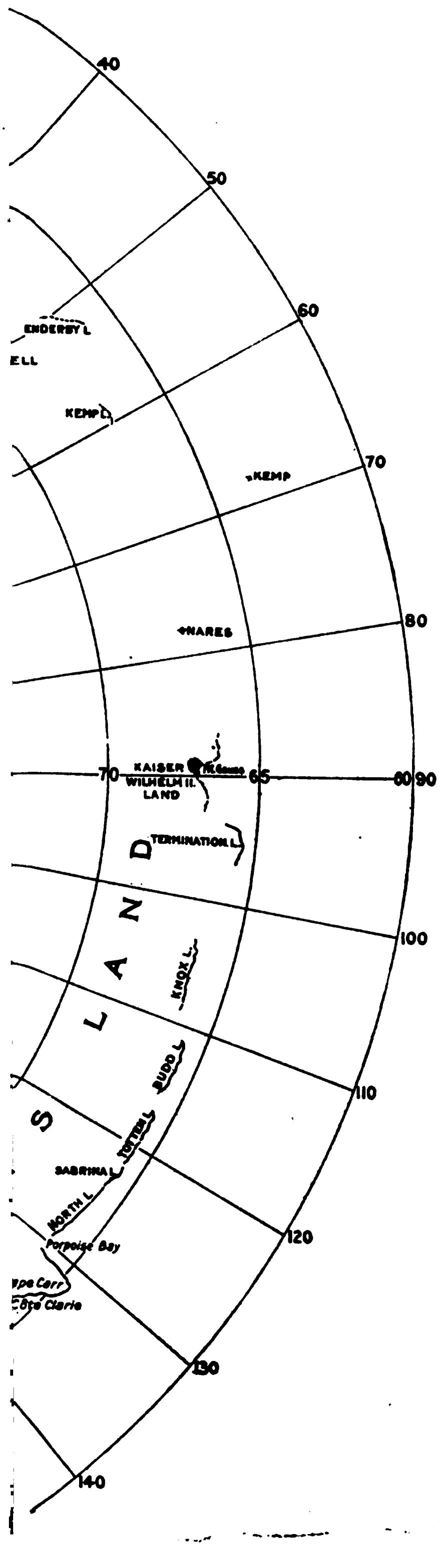
Shortly after Wilkes came the sealer Smiley, of whom there are unfortunately almost no records. There is one, however, hitherto unnoticed, which is interesting. On a globe, manufactured by Gilman Joslin in Boston and copyrighted by Charles Copley in Washington in 1852, which is now in the Academy of Natural Sciences in Philadelphia, is charted "South Shetland" and south of this in about 69° S. lat. "I. of Alexander," and in about 72° S. lat. "Smilies I." Smiley is known to have gone far south, but whether he actually went beyond Alexander Land, or was only the second to resight the Russian discovery, can, however, not be inferred from this. In our generation many voyages have been made by American sealers, Captains Osbon, Eldred, Glass, Buddington, Lynch, Fuller and others, principally to various parts of West Antarctica in a search for fur seal skins.

To-day, however, America is no longer doing her share in the exploration of the continent discovered by Americans. Other nations are doing all the work and reaping all the glory. The "Frozen White Continent" remains the one great unexplored area on the surface of the earth, and towards the end of the nineteenth

century, it began to exercise the irresistible fascination of the unknown on the thoughts of geographers and explorers. And nobly have Europeans answered the call. A Belgian expedition, under de Gerlache, explored the strait which bears his name, and traced by soundings a long piece of the continental shelf of West Antarctica. A mixed expedition, under Dr. Borchgrevink, wintered in Victoria Land. A German expedition, under Dr. von Drygalski, discovered a new portion of the coast of East Antarctica, Kaiser Wilhelm II. Land, and confirmed the existence of Wilkes' Termination Land. A Swedish expedition, under Dr. Nordenskjöld, explored and charted the eastern coast of the northern mainland of West Antarctica, the unnamed stretch of which, between King Oscar II. Land and Joinville Island, should certainly bear the name of "Nordensjöld Land." A Scotch expedition, under Dr. Bruce, sailed and sounded in the Weddell Sea, and discovered an unknown part of the coast of Antarctica, "Coats Land." An English expedition, under Captain Scott, explored and charted Victoria Land and discovered King Edward VII. Land. A French expedition, under Dr. Charcot, reëxplored Gerlach Strait and the outlying archipelago, and sighted, south of Graham Land, a new piece of coast, which Charcot called "Loubet Land," but which might well be renamed "Charcot Land." An English expedition, under Lieutenant Shackelton, last January reached, it is reported by cable, 88° 23′ S. lat., 162° E. long., and also the South Magnetic Pole, 72° 25′ S. lat., 154° E. long. And, at the present moment, a French expedition, under Dr. Charcot, is wintering somewhere in West Antarctica.

Is it not time for America to once more put her shoulder to the wheel and help science dispel ignorance? And if she does, what ought she to do? She ought to reëxplore Wilkes Land, and get a more accurate chart of its shores. Why? First, because Wilkes Land is an American discovery; second, because little is known about it; and third, because so much doubt has been cast on Wilkes and Americans by some foreign geographers.

I say but little is known of Wilkes Land. For some reason explorers have fought shy of its icy shores. The French admiral Dumont d'Urville landed in one bay of its coast; the English sealer Balleny caught a glimpse of it at one spot; and the German Dr. von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BUDD L.
TOTTEN L.
SABRINA L.
NORTH L.
Porpoise Bay
ape Carr
Côte Clarie

Drygalski reached the extreme western end: otherwise nothing has been done there since the immortal cruise of gallan Charles Wilkes.

The doubts and slurs cast on Wilkes's discovery are another paramount cause why Americans should reëxplore Wilkes Land. It should be looked on as a national duty to do so. It is unfortunately necessary in this connection to speak anew of the abuse and the disbelief heaped on Wilkes. The whole trouble was started by Sir James Clarke Ross. Angered at being forestalled in the discovery of Antarctica, Ross wrote most unfairly about Wilkes. Although Ross had Wilkes's book before him, and could read there the "Instructions"[8] directing Wilkes to go to the Antarctic, yet Ross wrote as if Wilkes had no business to do so when an English expedition was expected to go there the following year. Ross did not go to Wilkes Land nor anywhere near it, yet he deliberately left all of Wilkes's discoveries off his chart.[9]

Accepting the angered fancies of Ross as facts, many writers wrote disparagingly of Wilkes.[10] The most vehement of his opponents was Sir Clement R. Markham, who, after many times speaking of Wilkes as if Wilkes were utterly unreliable, finally reached the stage when he thought he could simply omit all reference to American Antarctic explorers. Owing to his important position, however, of president of the Royal Geographical Society, Markham's opinions naturally carried great weight in England and affected the judgment of younger men, chief among whom was Captain Robert F. Scott.

Captain Scott commanded the British Antarctic expedition to Victoria Land in 1901–1904. On his return northward, when in about the latitude of Hudson Land, he altered his course, and sailed due west for about nineteen degrees of longitude. When within about fifteen or twenty miles of Wilkes's "Cape Hudson," Scott turned northward and returned to Australia. He therefore did not go to any part of Wilkes Land. Nevertheless he asserts with the greatest emphasis in his book[11] that once for all he has definitely

[8] "Narrative United States Exploring Expedition," Vol. 1, p. xxvii.

[9] "Voyage of Discovery and Research in the Southern and Antarctic Regions." See "Antarctica," by Edwin Swift Balch.

[10] See "Antarctica," by Edwin Swift Balch, pp. 169, 176–178, 211.

[11] "The Voyage of the Discovery."

disposed of Wilkes Land and that it must be expurgated from the charts. But as Captain Scott did not go to Wilkes Land, his ukase about it, which is really nothing but a reflex of Sir Clements R. Markham's anti-American prejudices, will be politely pigeonholed by the douma of world geographers. Captain Scott is also quite unconscious of the fact that Hudson Land may easily be fifty or one hundred miles further south than Wilkes supposed, and that even if this is so, it would not in the least invalidate Wilkes's discovery.

Captain Scott's chart shows his track towards Wilkes Land and his turn away from it. Scott admits that he was on the continental shelf, because he took soundings four times in shallow waters. But there is a curious fact connected with these four soundings. In Scott's book they are given as 250 fathoms, 254 fathoms, 245 fathoms, and 260 fathoms; but on Scott's chart they are given as 256, 354 y. m., 248 m., 264 m. Not only does Scott disagree with himself about these soundings, but he disagrees with Lieutenant Armitage, his second in command, who in his book[12] puts down these soundings as 256 fathoms, 354 fathoms, 284 fathoms, and 264 fathoms, and says: "Although we did not see land, our soundings indicated that it was not very far off." Moreover Scott and Armitage also disagree about the weather. Scott says: "The sky has been dull, but the horizon quite clear; we could have seen land at a great distance;" but Armitage says: "The weather was not the kind in which one could see any great distance." It is to be hoped that Captain Scott's other observations are less contradictory than those he made near Wilkes Land, whose proximity apparently affected his observing powers.

Probably, however, the most curious fact in regard to Sir J. C. Ross's and Captain Scott's decision to expurgate Wilkes Land out of the world, is that the expeditions which they respectively commanded proved absolutely the existence of Wilkes Land. For they discovered and explored Victoria Land. And Victoria Land, a long range of high mountains, fronting to the east on Ross Sea and the Great Ice Barrier, is backed on the west by an ice cap some 9,000 feet in thickness. Now this ice cap, the main plateau of East Ant-

[12] "Two Years in the Antarctic."

arctica, cannot vanish into thin air or disappear in a hole in the ground: it must have a northern and western edge somewhere. And common sense points out that the northern and western edge of this great ice plateau is Wilkes Land.

II.

While it is perhaps impossible to determine positively who first suggested an American Antarctic expedition, it is probable that it was Dr. Frederick A. Cook. As far back as 1894, he published a paper "A Proposed Antarctic Expedition."[13] Dr. Cook wished to explore the northern mainland and islands of West Antarctica, and thought $50,000 would cover the expenses. His proposition unfortunately met with no response, or the discoveries of Palmer and Pendleton would doubtless have been verified and enlarged by Americans.

In the year 1899 Mr. Albert White Vorse published a strong plea[14] in favor of an American Antarctic expedition, winding up in

> What, then, is the profit in dragging out of the dust of libraries its forgotten scandals? There can be but one excuse for it: the hope that national pride may be moved to send forth a second Antarctic expedition that shall retrieve the mistakes of the first one. . . . Is it well for the United States to be behind in scientific research, or to permit other nations either to disprove or verify the report of its first attempt at foreign exploration?

Mr. Vorse's words, however, were barren of result.

In 1903, an Englishman, Dr. Hugh Robert Mill—whose recent excellent book "The Siege of the South Pole" is so different from old-fashioned works about Antarctic history—in a note to *Science* in reply to one of the writer's, also suggested sending an American expedition to the Antarctic. Dr. Mill said:[15]

> Yours is a land of millionaires: the Antarctic is still scarcely touched by explorers, and all nations would rejoice to see a well-equipped American expedition sent out to help to solve the present problems which, after all, are those most nearly concerning us.

[13] "Around the World," Philadelphia, February, 1894, p. 55.

[14] *Scribner's Magazine*, 1899, Vol. 36, p. 704.

the following words:

[15] *Science*, Vol. XVIII., August 7, 1903.

The writer immediately answered:[16]

The final suggestion of Dr. Mill deserves unqualified approval. Would it not be possible to send an American expedition, either private or governmental, to reëxplore the coast of Wilkes Land? A steamship like the "Bear," commanded by naval officers, should be able, in the course of one southern summer, to bring back fresh data about the land discovered by Americans in East Antarctica.

Here the matter slumbered again.

When Captain Scott, however, published[17] his unwarranted, inaccurate statements about Admiral Wilkes, the writer wrote two articles, "Antarctic Nomenclature"[18] and "Wilkes Land."[19] The latter article wound up in these words:

And now to take up another phase of this question. The whole of East Antarctica may be one great land mass. Or it may be that Wilkes Land is one mass, possibly a continuation of Australia; and Victoria Land one mass, possibly a continuation of New Zealand. No one can say positively, until an expedition is sent out to explore systematically the northern coast of East Antarctica. Mr. Henryk Arctowski, a member of de Gerlache's Antarctic expedition, is trying hard to keep up interest in Antarctic exploration and to have international coöperation in the future, as he has explained in a recent monograph. Is it impossible to wake up governmental interest in the United States in this matter, or, if it is, would not some American multi-millionaire furnish the funds to send an expedition to settle for all time the facts about the greatest geographical discovery of the nineteenth century, the coast of "The Antarctic Continent" discovered by Charles Wilkes?

In an editorial commenting on these articles, the *New York Tribune*[20] said:

It is extremely unfortunate that Captain Scott did not extend his survey to the precise spot at which Wilkes made his historic observations. Few disinterested geographers will attach any value to his report so far as the reality of Wilkes Land is involved. To assume on the strength of such evidence that any mistake has been made heretofore is premature, to say the least. Not until a new expedition has gone to the region in question and has made a more thorough search than did Captain Scott would it be wise or honest to drop the name Wilkes Land from Antarctic charts. For

[16] *Science*, Vol. XVIII., September 4, 1903.

[17] "The Voyage of the Discovery." See *supra*, Mr. Newberry's letter.

[18] *Bulletin American Geographical Society*, December, 1905.

[19] *Bulletin American Geographical Society*, January, 1906.

[20] February 5, 1906:

the honor of this country and of one of her ablest naval officers it is to be hoped that the point at issue may be thoroughly investigated before many years. A special expedition for the purpose might well be organized in America.

As a result also of these articles, the American Geographical Society took up the matter and sent the following letter to the Secretary of the Navy:

February 15, 1906.

Sir:

The council of this society respectfully invite your attention to the following passage from "The Voyage of the Discovery," by Robert F. Scott, R. N., London, 1905, Vol. II., page 392:

"The sky has been dull, but the horizon quite clear; we could have seen land at a great distance, yet none has been in sight, and thus once and for all we have definitely disposed of Wilkes Land."

This authoritative utterance by a recent explorer in the Antarctic is but the culmination of a series of representations, continued through sixty years, reflecting on the importance of the work accomplished by the U. S. Exploring Expedition of 1838–1842, under the command of Lieutenant Charles Wilkes, U. S. N.

Wilkes Land is the name given by map makers to the land discovered by Wilkes on the nineteenth of January, 1840, in E. long. 154° 30′, S. lat. 66° 20′, followed for 1,500 miles, and called by him The Antarctic Continent.

No subsequent explorer has followed his track.

It is hoped that it may be the purpose of the government to dispatch a vessel in order to verify the results of the exploration made by Wilkes, and this society will appreciate information on this point.

Respectfully,

CHANDLER ROBBINS,
Domestic Corresponding Secretary.

The Hon.
The Secretary of the Navy,
Washington, D. C.

Mr. Truman H. Newberry, Acting Secretary of the Navy, replied in the following letter:

NAVY DEPARTMENT, WASHINGTON, March 8, 1906.

Sir:

Replying to your letter of the 15th ultimo, inviting, on behalf of the Council of the American Geographical Society, attention to a certain passage from "The Voyage of the Discovery," by Robert F. Scott, London, 1905, Vol. II., page 392, therein quoted, to the effect that the vessel in question on her homeward voyage from Victoria Land, in March, 1903, crossed the track that had been followed in January, 1840, by the vessels of

the U. S. Exploring Squadron without seeing any of the lands that had been indicated by Wilkes as lying southward of the "Icy Barrier," between the meridians of longitude 154° and 158° east of Greenwich, and stating it is hoped that the Government will dispatch a vessel in order to verify the results of the Wilkes Expedition: I have to inform you that the Hydrographer of the Navy Department, to whom you letter was referred, has submitted the following comments thereon:

"On the nineteenth of January, 1840, in longitude 154° 30′ east, latitude 66° 20′ south, Lieutenant Charles Wilkes sighted, or believed that he sighted land to the south. On the same day, in longitude 153° 40′ east, latitude 66° 31′ south, Lieutenant Hudson also thought that he saw land to the south. Other officers of the expedition, among them Lieutenant Alden, Gunner Williamson, and Passed Midshipman Colvocoresses, made statements to the same effect. The American vessels sailed westerly, and on the 22nd and 23rd of January reported land again. They then continued their cruise in a westerly direction along this coast for a distance of about 1,500 miles, to longitude 97° 37′ east. Returning to Sydney, Australia, on the 11th of March, 1840, without touching at any intermediate port, Lieutenant Wilkes announced his discovery in a report to the Secretary of the Navy on the day of his arrival at Sydney, in the following words: 'It affords me much gratification to report that we have discovered a large body of land within the Antarctic Circle, which I have named the Antarctic Continent, and refer you to the report of our cruise and accompanying charts, inclosed herewith, for full information relative thereto.'

"At page 18 of Volume One of 'The Voyage of the Discovery,' published in 1905, Captain Scott makes the following statement:

"'Wilkes with his five ships sailed from Sydney at the end of December, 1839. His ships took various tracks, but he himself in the 'Vincennes' reached latitude 66° S., longitude 158° E., on January 16, and at this point point he claimed to have first seen land to the south. Hence he cruised to the westward, approximately on the latitude of the Antarctic Circle, with a comparatively open sea to the north and masses of pack-ice to the south; and beyond the latter he again and again claimed the discovery of high mountainous land. He passed close to Adélie Land and Côte Clarie only a few days after their discovery by D'Urville, and continuing his cruise, alleged the discovery of further extensive lands to the westward.

"'On his return to civilisation Wilkes claimed a vast discovery. The courses of his ships had practically traversed an arc of the Antarctic Circle of no less than 70°, and, although he did not assert that he had seen land continuously south of this arc, he reported its existence at such frequent intervals as to leave little doubt that it was continuous.

"'At a later date a great controversy arose as to the accuracy of Wilkes's observations, and resulted in much discredit being thrown on work which in many respects was important. Whilst there can be no possible object in attempting to revive such a controversy, it is evident that the true geographical condition should be known, and therefore I make bold to give my opinion of the matter. In the course of this narrative I shall show that

the mountainous lands reported by Wilkes to the eastward of Adélie Land do not exist, and it must be recognized that those to the west may be equally unsubstantial, but it is not clear that Wilkes wilfully perverted the truth; only those who have been to these regions can realize how constantly a false appearance of land is produced, and no position could be more favorable to such an illusion than that in which this expedition was placed when it skirted the edge of a thick pack containing innumerable icebergs. It must be supposed also, for reasons which I have given, that Wilkes, in common with other explorers, expected to find land about the Antarctic Circle, and when after his return he learned of D'Urville's discoveries, the position of Adélie Land would naturally have tended to dispel any doubt which he may have had as to what he or his people had seen.

"'Wilkes's ships were ill adapted for battling with the ice, and, apart from their discoveries, the fact that they continued so long in high latitudes reflects great credit on their navigation. Had he been more circumspect in his reports of land, all would have agreed that his voyage was a fine performance.'

"Captain Scott's statements about the non-existence of lands which Lieutenant Wilkes reported to be situated in the vicinity of the Antarctic Circle, between the meridians of longitude 97° and 158° east of Greenwich, rest upon the fact that, in her voyage homeward from Victoria Land, on March 4, 1903, the "Discovery," in longitude 154° E., crossed the track that had been followed in January, 1840, by the vessels of the U. S. Exploring Squadron without seeing any of the lands that had been indicated by Wilkes as lying southward of the Icy Barrier between the meridians of longitude 154° and 158° east of Greenwich. It is with reference to this incident of the approach to the crossing of the tracks of the two expeditions that the language quoted as follows in the letter of the American Geographical Society has been used.

"'The sky has been dull, but the horizon quite clear; we could have seen land at a great distance, yet none has been in sight, and thus once and for all we have definitely disposed of Wilkes Land.'

"Even if it be admitted that there is no land at the crossing where Captain Scott did not see any, this fact should not operate to induce a conclusion that, within the extent of the remaining 50° of longitude through which the United States Expedition skirted the Antarctic Circle, land does not exist."

There is no vessel of the Navy available at the present time for dispatching on a voyage of discovery to the Antarctic regions to verify the results of the exploring expedition (1838–1843) under the command of the late Captain Charles Wilkes, U. S. N.

Very respectfully,

TRUMAN H. NEWBERRY,
Acting Secretary.

Mr. Chandler Robbins,
Domestic Corresponding Secretary,
The American Geographical Society,
15 West 81st Street,
New York, N. Y.

In forwarding copies of these letters to the writer, the late George C. Hurlbut, librarian of the American Geographical Society, wrote as follows:

March 12, 1906.

My dear Mr. Balch:

We received on the 10th an answer to the letter written to the Secretary of the Navy about a ship for the Antarctic, and I enclose a copy for you.

It is final for the time, but no one knows what may come to pass.

Sincerely yours,
GEORGE C. HURLBUT.

Miss Wilkes, the daughter of our great explorer, also sent the writer the following letter:

814 CONNECTICUT AVENUE,
WASHINGTON, D. C.

My dear Sir:

Your ideas as to an Antarctic expedition to substantiate my father's discovery of a continent appeals more and more to my sister and me. We hope that you will see fit to endeavor to persuade some government official or some man in power politically or financially to work upon and push your plan to successful completion calling it the "Balch Expedition." If we can do anything in our little way to bring your idea into notice, we shall gladly speak or write.

But alas! we are women, not ever of much use in such grand projects as you, with your knowledge and courage in speaking for the truth, are so fitted to undertake. It was really a happiness to talk with you, who have done so much to uphold my father's name. My sister and I both regretted very much that she too had not the gratification of meeting you and your wife. We will hope to see you both in Washington when you come, with your admirable manner and convincing words to lay your most kind intention before the officials here. With most grateful thanks to you and regards to your wife,

Very cordially,
ELIZA WILKES.

April 12, 1906.

Not long after this, the writer succeeded in enlisting a powerful helper in the cause of Antarctic exploration. This was Commander Robert E. Peary, who up to this time, curiously enough, had apparently taken no interest whatever in the Antarctic. Indeed, in his letter of September 2, 1903, explaining his plans for a new Arctic expedition to the Secretary of the Navy, Commander Peary showed that he was unaware that there was a south polar problem, when he wrote:[21]

[21] *Bulletin American Geographical Society,* Vol. XXXV., 1903, p. 375.

The North Pole is the last great geographical prize the earth has to offer. Its attainment will be accepted as the sign of man's final physical conquest of the globe; and it will always stand as one of the great milestones in the world's history.

The attainment of the North Pole is, in my opinion, our manifest privilege and duty. Its attainment by another country would be in the light of a reproach and criticism.

To which the Acting Secretary of the Navy, Mr. Charles H. Darling, replied very sensibly,[22] showing that he recognized that the South Pole was just exactly as important geographically as the North Pole:

The attainment of the Pole should be your main object. Nothing short will suffice. The discovery of the Poles is all that remains to complete the map of the world. That map should be completed in our generation and by our countrymen.

Commander Peary also made no reference to south polar problems in his book "Nearest the Pole," published in 1907.

In December, 1906, however, the writer sent a copy of "Antarctica" to Commander Peary, also calling his attention to the article "Wilkes Land." Commander Peary replied as follows:

WASHINGTON, D. C.
December 14, 1906.

Dear Mr. Balch:

I have the copy of "Antarctica" and thank you very much for the valuable present. I shall read it through at the earliest possible opportunity.

The accompanying pamphlets are also extremely interesting. Accept my best thanks for all.

The references which you give I shall certainly look up and add to my library.

I greatly appreciate your kindly words and look forward to the pleasure of seeing you again on the 21st.

Very sincerely,

R. E. PEARY,
2014, 12th Street, N. W.

Commander Peary, after the necessity for American exploration in the Antarctic was brought thus to his notice, evidently studied up the matter and in 1908 he put himself on record as willing to

[22] *Bulletin American Geographical Society,* Vol. XXXV., 1903, p. 376.

undertake the task of organizing an American Antarctic expedition by sending to the *Commission Polaire Internationale* a "communication" which was presented by Mr. Herbert L. Bridgman, president of the Peary Arctic Club. In this "communication" Mr. Peary says:

> I beg to state that on my return from my coming Arctic Expedition, I shall endeavor in every possible way, consistent with my other duties, to promote and organize a National American Antarctic Expedition, to secure for this country its share of the honors and valuable scientific information still awaiting the explorer in that region.

The fact that Commander Peary has at length become interested in the Antarctic regions and is indorsing the writer's cherished views in such a practical way, renews hope that before long an American expedition will be on its way to Wilkes Land.

III.

There is an almost unlimited field for scientific research and observation in south polar regions, and many branches of natural science will be advanced by properly equipped expeditions. Geography, oceanography, glacialogy, geology, palæontology, zoölogy, bacteriology, meteorology, magnetism, all need many more years of study in the south by trained observers. There are some scientific problems of the first magnitude awaiting solution. One of them, for instance, is the Great Ice Barrier. It appears to be afloat as far back as observed and to be moving. Where does it extend to? What formed it? What causes its motion? No one can say! To solve this wonderful glacial problem would be worth all the money spent to do so.

In zoölogy, in ichthyology, in bacteriology, in botany—in fact in regard to life in all its forms—there is any amount of work still to be done in the Antarctic. For an American expedition, however, collecting would be more important than observing on these lines, because, although so many American vessels have visited south polar regions, neither the American Museum of Natural History, nor the United States National Museum, nor indeed any of the great museums in America has anything like a repre-

sentative collection from Antarctica, and therefore one of the most fruitful results of an American expedition would be to bring home specimens of all kinds.

But geography is the most pressing science. The interior of Antarctica is almost unknown. The coast line is not half laid down, even if the continental shelf has been traced by soundings in several places where land has not been sighted as yet. And the paramount geographic duty for Americans should be a more accurate charting of the coast line of Wilkes Land, which could be largely done even in one southern summer by two steam whalers.

Starting about the middle of December from Australia, an American expedition should aim for Piner Bay in about 140° east longitude, and thence it should sail eastward to about 170° east longitude. It should, while avoiding getting caught in the ice, hug the coast as much as possible. Such a cruise would settle for all time the question of the existence of the great land mass of East Antarctica. It would also prevent any possible wrangling in the future about Case Land, and Alden Land, and Hudson Land, which will all probably turn out to be fifty or seventy-five miles further south than Wilkes charted them.

Is there now any way of bringing about such an expedition? The United States government, practically speaking through Mr. Newberry, Acting Secretary of the Navy, declined to take the matter up. What can be done either to induce the government to rescind its negative decision, or towards finding some private individuals to finance the undertaking?

It would seem as though the first thing to do would be to arouse more general interest among scientific men. The American Geographical Society has already shown approbation. Would not some of the learned societies in the United States, such as the American Philosophical Society, the Smithsonian Institution, and the American Museum of Natural History endorse the project in some shape or other?

If some of the geographic and scientific societies would put the seal of their approval on an American Antarctic expedition, the next step forward would seem to be the formation of an Antarctic

Committee, each member of which should represent some scientific or geographic society in the United States. If a committee were formed, of such men as Cyrus C. Adams, Herbert L. Bridgman, Henry G. Bryant, Hermon C. Bumpus, William Morris Davis, Charles E. Fay, Adolphus W. Greely, Gilbert H. Grosvenor, George W. Melville, Robert E. Peary, Winfield Scott Schley, Harvey M. Watts, each one chosen from some learned body like the American Philosophical Society, the Smithsonian Institution, the American Museum of Natural History, the Franklin Institute, the American Geographical Society, the National Geographic Society, the Peary Arctic Club, the Appalachian Mountain Club, the American Alpine Club, the Association of American Geographers, etc., and such a committee would issue and distribute some memoirs on the importance of Antarctic research, public interest might be aroused and the matter take a concrete form.

When one considers all the facts in the case—that the last unknown continent was discovered by Americans; that the commander of our most successful expedition was immediately arraigned and attacked by the angry commander of the next British expedition; that a recent ex-president of the Royal Geographical Society and also the commander of the British National Antarctic expedition are eager to wipe out all American discoveries from the map; that many branches of science would be advanced; that big gaps in American museums would be filled; and above all, that the discoveries by the United States Navy in the Antarctic would be verified and increased—it would seem as though some Americans would take the matter up, and, while helping science, link their names with that of our great Antarctic explorer.

THE NATION AND THE WATERWAYS.

By LEWIS M. HAUPT, C.E., A.M., Sc.D.

(Read April 22, 1909.)

This mysterious planet which we inhabit has been the object of profound reasearch by many self-constituted investigators since the creation of man, yet he has not wholly unravelled her secrets nor fathomed her innumerable resources.

She may be likened to an immense gyroscope, whose pole is the sun and whose radius-vector is the tether which checks her eccentricities as she floats through space. Her form, size and density have been carefully determined and it is found that of the four great circles which constitute her envelope, only about 53,500,000 square miles are above the level of the sea, and that of this portion but about 28,000,000 are arable land.

Such is the present extent of our heritage, as a storehouse for the maintenance of life, and it is recorded that when, in the process of time, this physical orb had been suitably developed for habitation, then the Lord God, by His creative Word, said:

> "Let us make man in our image, after our likeness and let them have dominion over all the earth. . . . So God created man and blessed them and said unto them, 'Be fruitful and multiply and replenish the earth and subdue it; and have dominion over . . . every living thing that moveth upon the earth.'"

In the fulfillment of this divine commission man has multiplied in numbers, notwithstanding many vicissitudes, until to-day it is estimated that there are not less than 1,500,000,000 souls to be supplied with the necessities of life, yet the earth is not full, nor are her resources exhausted. This enormous host of humanity is scattered, more or less densely, over the habitable portion of the globe, subject to different environments, beliefs, aspirations, habits, governments, faculties and purposes, yet all imbued with the common,

imperious instinct of life, from the lowest barbarianism to the highest civilization.

To level up these hordes of humanity, free circulation, tending to promote community of interests, is necessary, and yet some of the most favored nations are enacting legislative barriers to prevent migration and restrict commercial intercourse, not only between nations but even between states.

From these two factors of available area and present population it appears that, if uniformily distributed, there would be a density of 53.6 individuals to the square mile, or 11 acres per capita. But it will give a better idea of the capacity of the earth to state that the entire population of the globe could be included in the State of Texas, at the rate of nine to the acre, whereas the safe sanitary limit is taken at one hundred per acre. Belgium, one of the most densely settled and prosperous countries, has a density of 1.12 acres per capita, or 0.9 of a person per acre.

The annual increment of the world is stated to be: births, 36,792,000; deaths, 35,639,835—difference or increase, 1,162,165. Were this rate to remain constant, on this basis, it would require over a thousand years to even double the present population, so that there would appear to be ample room for the normal increase even within present limits of territory. But these figures must be discredited inasmuch as they give only three fourths of one per cent. increment per *decade,* while the *annual* excess for Europe, as determined by Professor Marshall, was 1.06 per cent., or fourteenfold greater.

Suffice it to say, however, that while there appears to be ample room in the world for thousands of years to come, yet the increase in the United States is believed to be far more rapid than in any other country on earth. Here the rate is more than double that of Europe, and this fact also is an earnest of her influence as a world power in the maintenance of peace, regardless of great armaments. Large portions of the industrial world are dependent upon her granaries for their materials and subsistence, thus intensifying the necessity of reducing the cost of transportation and increasing her facilities, by providing capacious channels as well as an adequate merchant marine, for the distribution of her products.

This question of cheap transportation becomes, therefore, one of international importance, deserving of the careful consideration of all classes of people and, although much has been said and done to meet the demands of commerce, our retired President has characterized the results as being "largely negative," which he attributes to the absence of a comprehensive plan which led to the policy of "repression and procrastination," and he adds:

> "In spite of large appropriations for their improvement our rivers are less serviceable for inter-state commerce to-day than they were half a century ago, and in spite of the vast increase in our population and commerce they are on the whole less used."

This pregnant paragraph represents a condition resulting from a change of policy which has rendered these lamentable results possible, and which is so diametrically opposed to the fundamental principles of this democracy that a brief statement of these innovations seems essential to point out the proper remedy.

Fundamental Principles.

In his excellent analysis of the dangers threatening the utilities of the railroads, from legislative restriction, Mr. Stuyvesant Fish[1] calls attention to the words of Washington, when retiring from public life, as follows:

> "It is important, likewise, that the habits of thinking, in a free country, should inspire caution in those intrusted with its administration, to confine themselves within their respective constitutional spheres, avoiding in the exercise of the powers of one department, to encroach upon another. The spirit of encroachment tends to consolidate the powers of all the departments in one, and thus to create, whatever the form of government, a real despotism. A just estimate of that love of power, and a proneness to abuse it which predominates the human heart, is sufficient to satisfy us of the truth of this position . . . If, in the opinion of our people the distribution or modification of the constitutional powers be, in any particular, wrong, let it be corrected by an amendment in the way which the constitution designates. But let there be no change by usurpation for though this, in one instance, may be the instrument of good, it is the customary weapon by which free governments are destroyed."

Now, more than a century later, our distinguished Secretary of

[1] "The Nation and the Railroads," address before the American Academy of Political and Social Science. No. 553, 1908.

State and ex-U. S. Senator, P. C. Knox, in an address delivered February 12, 1908, said:

"When the Government assumed charge and control of the navigable streams of the interior it entered into a practical contract with the States and communities bordering these streams that their waterways should be improved to their highest capacity. The States were thereby prevented from improving the streams themselves. Corporate enterprise was forbidden to undertake the canalization of important stretches and fix the cost of their works and franchises on the traffic. The Federal Government has made its formal and deliberate declaration that it will do this work. That necessarily involves that it will make the improvements adequate to modern needs and possibilities. To do any less would be a mockery and breach of good faith."

Thus, it is manifest that the federal government has *assumed charge and control of* the waterways of the states, but without formal agreement, and has paralyzed the former corporate or local initiative as commercial enterprises, and in consequence of the inability of the national treasury to meet even a small fraction of the demands upon it for this class of public works, has added to the general congestion of the transportation and increased the cost.[2]

The great relative loss in water-borne commerce during the past half century may be ascribed in large part to the rapid increase in the mileage and capacity of railroads which have erroneously regarded waterways as competitors and waged a war of extermination upon them; as well as to the policy on the part of some of the states and localities to tacitly prefer appropriations from the national treasury rather than from their own revenues and thus apparently sanction the forfeiture of sovereignty over these works, to an extrinsic authority, having no constitutional rights to exercise them.

Even if it were constitutional for the general government to assume and control the improvements of all the rivers and harbors of the several states, it has been demonstrated time and again that it is impracticable to secure the necessary appropriations from the general treasury, necessary to meet the demands of a rapidly expanding commerce, which furnishes a tonnage increasing five-fold faster than the facilities for transporting it. With all sections

[2] At the closing session of the 60th Congress the appropriation was only *nine-tenths* of *one per cent.*, while 60.5 per cent. was for militarism and its sequences.

clamoring for expenditures in their districts for isolated improvements it becomes impracticable to enter upon any continuous and systematic plan of relief. The frequent failure of the appropriation bill for waterways is in itself conclusive evidence of the serious obstacles to the development of these works due to general legislation, and the paralysis resulting from the assumption of control over all such works by a central authority is too often in evidence. With the many devices available for the defeat of meritorious legislation, the issue is always in doubt and is frequently determined by the policy of the "steering-committee" or the demands from other departments or bureaus of the executive departments, which have their headquarters at the capital, and are in position to direct legislation by making or withholding recommendations for certain influential sections. Thus, the multitude of bills, the shortness of the closing sessions, the reference to committees not having the right of way on the floor, the ability to filibuster or talk a measure to death through courtesy, the reference to a committee with instructions to pigeon-hole, the failure of a member to receive recognition, the necessity of distributing the patronage over the country to secure a sufficient number of votes to pass the bill, the strenuous opposition of vested interests fearing competition, and the local, sectional jealousies existing between adjacent centers, all tend to retard or defeat the normal development of our avenues of transportation and to promote those of our foreign competitors in the markets of the world.

That these statements are not mere glittering generalities will appear by a brief reference to the history of the colonies when the rivalries of trade and the cutting of rates were so severe that to avoid impending ruin, it was determined to form a confederation to protect the colonies from the devastation of the foreign powers which were destroying their trade. Thus it was that the Constitution of the United States was adopted on the seventeenth day of September, 1787, whereby the states empowered the Congress to "regulate commerce with foreign nations and among the several states, and with the indian tribes."

Many are the expositions which have been published as to the scope and meaning of these powers, but the opinion of the framers of this Magna Charta, are unanimous as to the fact that *the states*

did not relegate their jurisdiction over their waterways, water-powers or franchises to the national government and this right was retained and exercised by the states to their great benefit, as well as to that of the nation, up to and after the Civil War when the policy gradually changed and the "control was assumed," as Senator Knox puts it, by the government. Under this policy of encroachment and national control, it has become necessary for all sections of the country to organize great political and local associations and to combine these into national congresses which assemble annually at the capital, to urge by every legitimate means that $500,000,000 bonds be issued, to enable the waterways of the country to be prepared for traffic, yet the results thus far are almost negligible, and it is stated by members of Congress that the people would not justify such measures. This opinion appears to be well supported by the fact that during the past half century more than $600,000,000 have been appropriated for these purposes from the public treasury and yet the President has declared that the results are largely negative, but the method of procedure would seem to be radically wrong in basing the appeal for money on the experience of the past with no prospect of better returns for the future, which can only be effected by a reformation of the system which has rendered such returns possible. Thus it happens that the largest and most enterprising commercial and trade organizations of the country are memorializing Congress for such a reorganization as shall place these works under a cabinet officer, to be created with definite and systematic plans for the continuous execution of such works as may properly come within the jurisdiction of the United States and to encourage the state, corporate and local initiative as was the practice in ante-bellem days when the waterways and canals were so rapidly and successfully developed at a minimum cost by private capital, as have been the railways and highways of the federal domain from its foundation. In short it is vital that there should be a return to the early policy underlying the foundation of this republic and which was the spirit embodied in its Constitution. It was the genius of our government, that

"What individual enterprise could effect alone, was to be left to individual enterprise; what a state and individuals could achieve together was

left to the joint action of states and individuals; but what neither of these, separately or conjoined were able to accomplish, that and that only, was the province of the federal government."

In the application of this principle as construed under the Constitution is it asserted that the recent practice of appropriating public moneys for projects which are essentially and indisputably designed to benefit local and personal interests is radically wrong. This attitude was firmly maintained by many of our Presidents from Washington to the present time.

Thomas Jefferson, long president of this distinguished society, who was the first Secretary of State, under the Constitution, and also vice-president from March 4, 1797, to 1801 and President of the United States for the two following terms during the formative days of the Republic, in his sixth annual message to Congress, dated December 2, 1806, refers to the prospective plethora of income from imposts and suggests the desirability of expending a portion of these funds upon public improvements but states emphatically that it will require an amendment to the Constitution as it is not authorized under the powers vested in Congress. He recommended the abolition of the imposts on the necessary articles of trade and their continuance on foreign luxuries, appealing to the patriotism of those who were able to pay for their use that the revenues might be applied

"To the great purposes of the public education, roads, rivers, canals and such other objects of public improvements as it may be thought proper to add to the constitutional enumeration of the federal powers. By these operations new channels of communication will be opened between the states, the lines of separation will disappear, their interests will be identified and their union be cemented by indissoluble ties. . . . The subject is now proposed for the consideration of Congress, because, if approved by the time the state legislatures shall have deliberated on this extension of the federal trusts, and the laws shall be passed and other arrangements made for their execution, the necessary funds will be on hand without employment. I suppose an amendment to the Constitution, by consent of the states, necessary, because the objects now recommended are not among those enumerated in the Constitution, and to which it permits the public moneys to be applied."

So that as the Constitution has never been thus amended it would appear that many of the appropriations which have been made from the public treasury are without warrant in law.

A few years later when the necessity of greater facilities became still more manifest, his successor, President James Madison, also urged that Congress should pass enabling legislation by amendment to the Constitution and felt required under his oath of office to veto a bill passed by Congress appropriating public money for works of this class, in the following words:

"March 3, 1817: Having considered the bill this day presented to me entitled 'An act to set apart and pledge certain funds for internal improvements, and for constructing roads, and canals and improving the navigable water courses, in order to facilitate, promote and give security to internal commerce among the several states, and to render more easy and less expensive the means and provisions for the common defense,' I am constrained by the insuperable difficulty I feel in reconciling the bill with the Constitution of the United States to return it with that objection to the House of Representatives, in which it originated. . . .

"The power to 'regulate commerce among the several States' cannot include a power to construct roads and canals and to improve the navigation of water courses in order to facilitate, promote and secure such a commerce, without a latitude of construction departing from the ordinary import of the terms strengthened by the known inconveniences which doubtless led to the grant of this remedial power to Congress. . . .

"If a general power to construct roads and canals and to improve the navigation of watercourses, with the train of powers incident thereto, be not possessed by Congress, the assent of the states to the mode provided in the bill cannot confer that power. . . .

"I am not unaware of the great importance of roads and canals and the improved navigation of water courses, and that a power in the national legislature to provide for them might be exercised with signal advantage to the general prosperity. But seeing that such a power is not expressly given by the Constitution, and believing that it cannot be deduced from any part of it without an inadmissible latitude of construction and a reliance on insufficient precedents; believing also that the permanent success of the Constitution depends on a definite partition of powers between the general and the state governments, and that no adequate landmarks would be left by the constructive extension of the powers of Congress as proposed in the bill, I have no option but to withhold my signature from it, and to cherish the hope that its beneficial objects may be attained by a resort for the necessary powers to the same wisdom and virtue in the nation which established the Constitution in its actual form and providently marked out in the instrument itself a safe and practicable mode of improving it as experience might suggest."

As these Presidents were contemporaneous with the framing of the Constitution their official interpretation of its powers and scope

should carry great weight, indicating as they do the fear of trenching on the rights of the states and checking their development by trespassing upon their own resources.

Presidents Jackson, Tyler, Polk and Pierce also emphasized these views by their emphatic vetoes and even after the war, when Congress had adopted a policy of making such appropriations, Presidents Grant, Arthur and Cleveland vetoed bills, while others failed of passage because they did not contain enough patronage for local projects to secure the necessary votes. This pernicious principle, which was feared by the founders of the republic, was clearly shown in the application of the State of New York for federal aid in the construction of the Erie Canal, a work of undoubted national import. When its legislature sent a committee to Washington on December 21, 1811, President Monroe stated that he was embarrassed by scruples derived from his interpretation of the Constitution. The next day, the Secretary of the Treasury, Albert Gallatin, of Pennsylvania, stated that he was under the opinion that pecuniary aid could not be given, but that sufficient grants of land might now be made without inconvenience to the fiscal affairs of the union. The opinion prevailed in Congress that it would be wise to amend the Constitution for such purposes, but the delegation felt it a

> "Duty to declare, on all proper occasions, a decided opinion that the States would not consent to vest in the national government a power to cut up their territory, for the purpose of digging canals."

It was also reported:

> "Your committee found another idea operating with baleful effect, though seldom and cautiously expressed. The population and resources of the State of New York furnish no pleasant reflection to men, whose minds are imbued with state jealousies; and although the proposed canal must not only be of the highest importance to the western states as well as to the States of Pennsylvania and Maryland, and greatly promote the prosperity of the whole union, it was obvious that an opinion as to its superior benefit to this state was sedulously inculcated. . . . It became evident that the object of this state would not be separately attended to and your committee were desired to prepare a general system . . . as being necessary to secure the consent of a majority of the House of Representatives. . . . Others again, who have too much understanding to doubt the resources of the state and

too much prudence to expose themselves to ridicule, by expressing such doubt, triumphantly declare, that her legislature has not the spirit and intelligence to draw out and apply her resources to that great object. These men console themselves with a hope that the envied State of New York will continue a suppliant for the generosity of the Union, instead of making a manly and dignified appeal to her own power. It remains to be proved, whether they judge justly who judge so meanly of our councils."

The sequel is well known and reveals the wisdom of abandoning all efforts to secure national aid, and to depend upon local resources and initiative for early developments, as was done.

In vetoing the bill on August 1, 1882, President Arthur said:

"My principal objection to the bill is that it contains appropriations for purposes not for the common defense or general welfare, and which do not promote commerce among the states. . . . I regard such appropriations of public money as beyond the powers given by the Constitution to Congress and the President. I feel the more bound to withold my signature because of the peculiar evils which manifestly result from this infraction of the Constitution.

"Appropriations of this nature to be devoted to purely local objects tend to increase in number and amount, etc. Thus as the bill becomes more objectionable it secures more support. This result is invariable and necessarily follows a neglect to observe the Constitutional limitations imposed upon the law making power."

Yet the passage of the bill in the face of this plain declaration of the evils to result therefrom indicates how great is the temptation to cater to one's constituency, at the public expense.

Commenting on the morale of similar appropriations in his day, President Jackson said in part, May 27, 1830:

"In the best view of these appropriations, the abuses to which they lead far exceed the good they are capable of promoting. The subject has been one of much, and, I may add painful reflection to me. It has bearings that are well calculated to exert a powerful influence upon our hitherto prosperous system of government, and which on some accounts, may even excite despondency in the breast of an American citizen."

Then denying the power of Congress to appropriate public money for local or private benefit, he added:

"This is the more necessary to preserve other parts of the Constitution from being undermined by the exercise of doubtful powers or of too great extension of those which are not so, and protect the whole subject against deleterious influences of combinations to carry by concert measures which, considered by themselves, might meet but little countenance."

This fear, which amounts to a prophecy, is fulfilled in the vast assemblages, conventions and caucuses which are found to be necessary to secure the predetermined policies of the dominant party, but the effect as applied to waterways is far more injurious because of the assumption of jurisdiction over *all possible waterways* in the United States or its possessions, so that even where the government is unable to make improvements it is now practically impossible for localities or private parties to inaugurate works on their own account and at their own risk. It is still further proposed to extend the powers of the government into the waters of the several states and make them a source of revenue to the general government by the imposition of royalties on the water-powers which are now or have been free, thus further taxing the industrial products of the Nation, at the expense of the consumers.

Another phase of these improvements, so called, is touched upon in the veto of President Cleveland which is worthy of careful consideration. After many years of experience in efforts to provide capacious channels at public expense, he stated on May 29, 1896, that:

> "Many of the objects for which it appropriates public money are not related to the public welfare, and many of them are palpably for the benefit of limited localities or in aid of individual interests. On the face of the bill it appears that not a few of these alleged improvements have been so improvidently planned and prosecuted that after an unwise expenditure of millions of dollars new experiments for their accomplishment have been entered upon. . . . These cannot fail to stimulate a vicious paternalism and encourage a sentiment among our people, already too prevalent, that their attachment to our government may properly rest upon the hope and expectation of direct and especial favors. I believe that no greater danger confronts us as a nation than the unhappy decadence among our people of genuine and trustworthy love and affection for our government as the embodiment of the highest and best aspirations of humanity and not as the giver of gifts, and because its mission is the enforcement of exact justice and equality, and not the allowance of unfair favoritism."

These patriotic opinions from the highest authorities, whose official positions qualify them to speak ex-cathedra, should suffice to convince the most skeptical of the necessity of some modification of the system which will give assurance of better returns for the money expended and for a restoration of the policy of local and

state aid in the development of local improvements. The great increase proposed in the amount of the appropriations gives no guaranty that the defects of the system will be remedied but rather increased. In commenting on the passage of the largest bill ever passed, namely that of 1907, for $87,113,432, it was stated that one item alone of over a million dollars was for a purely local scheme and although thoroughly exposed and denounced in the public press while the bill was pending, there was not a voice against it when the bill was passed. This was not the only one in the measure, yet to have cut them out would have caused the defeat of the entire bill.

> "If the rivers and harbors bills cannot be passed without such abuses, the system should be changed, and that quickly, for conditions could hardly be more demoralizing."

These conclusions are reiterated at almost every meeting of the National Board of Trade and of many commercial bodies all over the country, yet they are "more honored in the breach than in the observance."

At its recent session, the National Civic Federation resolved that such legislation should be passed as would preserve individual initiative, competition, and the free exercise of a free contract in all business and industrial relations. The National Board of Trade resolved:

> "That the public works of the government, excepting that of the military and naval establishments, be placed under the direction and control of a department to be created, which shall be called the Department of Public Works."

A natural sequence to the above exposé of the operation of the existing system, may be found in the inability to secure adequate appropriations from the public purse, at the last session, for works of internal improvements in the face of so great a deficiency threatening the Treasury, yet the sums allotted for the destructive agencies of war, navy and pensions were largely increased. The river and harbor appropriations aggregate less than one tenth of the former bill for this purpose and the money is limited to the "Repair, maintenance and preservation of these public works

heretofore appropriated for by Congress, and for continuing in operation such dredging and other plants or equipment of any kind owned by the United States government." Thus no extension of works is permitted and furthermore it is proposed to increase the dredging plants owned by the government doing work by the eight hour day and in open waters, without regulating works to maintain the channels so improved.

A brief analysis of the unprecedentedly large appropriation of 1907, indicates that more than one half is applied to transfer points on or near the seaboard and at terminals, so that the overland, domestic traffic is not materially relieved, while a large sum is also applicable to tentative works and to efforts to compete with the deteriorating forces of nature by mechanical devices, involving large annual expenditures for operation and maintenance.

A general review of the conditions which prevail as to the decadence of the waterways of the country, indicates that the assumption of authority by the government has operated to restrain state and corporate initiative, has reduced the available mileage of the canals to about one half that of 1860, has added largely to the expenses for maintenance and has rendered it difficult, if not impossible, to secure legislation for much needed local improvements because of the claims of governmental jurisdiction and control, thus destroying competition by water and preventing development.

Remedial Legislation.

Since it has been shown, *in extenso,* by citations from the highest authorities that the states have not surrendered their sovereign control over the local waterways included within their boundaries, and that it is practically impossible to secure national appropriations for such local improvements, save for political purposes, it would appear to be most practicable and necessary to confine the operations of the government to those interior waterways which are strictly interstate, and the improvement of which would promote the general welfare; such as the rivers which form borders between two or more states in whole or in large part, as in the case of the Mississippi, Missouri, Ohio, Delaware, Potomac, Savannah, Colum-

bia as far as Wallawalla, the Rio Grande, St. Lawrence and others, as well as to the principal harbors of the Atlantic, Gulf and Pacific with the Great Lakes and the internal canals connecting these *trunk lines.*

All other waterways lying within or traversing the areas of the several states, in whole or part, with local harbors, inlets, canals or other improvements should be emancipated from the assumed control of the government and be relegated to the states to develop under their reserved rights by the granting of charters to localities or private corporations as formerly, but any state or corporation desiring government aid may apply to Congress and receive such assistance as that body may deem justifiable, for the public good, said appropriations to be returned to the national treasury in due course as determined by the terms of the loan.

Thus by mutual coöperation and consent the tributary avenues of trade may be synchronously developed, as the trunk lines and terminals are enlarged, to meet the rapidly expanding demands of the country. Otherwise at the present rate it may require from fifty to one hundred years to meet the present requirements, with no prospect of overtaking those of the future for which the nation must wait and pay the extra charges for overland carriage. The engineering and administrative features of this pressing problem must be deferred for lack of time and because they are subordinate to the vital element of securing enabling legislation, involving as it does a reorganization of the system of control.

In the words of our immortal President Lincoln:

> "Let the nation take hold of the larger works, and the states the smaller ones; and thus, working in a meeting direction, discretely, but steadily and firmly. What is made unequal in one place may be equalized in another, extravagance avoided, and the whole country put on that career of prosperity which shall correspond with its extent of territory, its natural resources, and the intelligence and enterprise of its people."

If this policy of coöperations were rightly carried out it would conform to the fundamental conception of the framers of the Constitution to establish a government "of the people, by the people and for the people."

ON A NEW VARIETY OF CHRYSOCOLLA FROM CHILE.

By HARRY F. KELLER.

(*Read April 23, 1909.*)

Like other cryptocrystalline or amorphous minerals the hydrated silicates of copper collectively designated as chrysocolla vary considerably in their chemical composition. They also show very marked differences in color, some of the varieties being deep green, while others exhibit various shades of bluish-green and blue. In many instances the color of the mineral is doubtless modified by the presence of admixtures, such as the oxides of iron, manganese or copper, but we can hardly account for the existence of both the decidedly green and the pure blue modifications without assuming that they are different in composition. Thus in the case of the hydrated carbonates of copper, malachite and azurite, the difference in color is known to be due to a difference in the proportions of chemically combined water.

Now the analyses of certain green varieties of chrysocolla closely approach the composition $CuSiO_3 + 2H_2O$, but those of other occurrences, and particularly of the blue varieties, have yielded not only different proportions of silica, oxide of copper and water, but also notable quantities of other constituents, like alumina and phosphoric acid. Among several Chilean chrysocollas of which specimens were presented to me by my brother, Mr. Hermann A. Keller, there is one which appears to me of peculiar interest as its analysis may throw some light on the constitution of the blue varieties of the mineral. It was found at Huiquintipa in the Province of Tarapacá, and is in the form of turquois-blue, enamel-like crusts, disseminated through a honeycombed silicious matrix. It is brittle with a hardness of 3.5. The powder is of a pale greenish color. When heated in the closed tube, the mineral gives off considerable moisture and blackens, and it is readily decomposed by the mineral acids, without gelatinizing.

The analyses yielded:

	I. Per Cent.	II. Per Cent.	Calculated for $CuH_2(SiO_3)_2+2H_2O$ Per Cent.
Specific gravity	2.532		
SiO_2	46.14	45.89	47.31
CuO	28.85	28.69	31.39
Al_2O_3	.58	.47	
FeO	1.38	1.33	
CaO	1.64	1.67	
MgO	.83	1.01	
H_2O	20.15	20.32	21.30
	99.54	99.38	100.00

It was found, as a mean of several closely agreeing determinations, that two thirds of the water (13.41 per cent.) escapes below 125° C., while the remainder (6.83 per cent.) can be expelled only by protracted ignition at a red heat. There can be no doubt, then, that the latter portion is present in the substance as part of an acid salt, as in dioptase for example. Assuming that the other two thirds of the water is simply "water of crystallization" and, further, that the small amounts of iron, calcium, magnesium, etc., are admixtures, the formula calculated from the above analytical data is $CuH_2(SiO_3)_2 + H_2O$. This differs from the composition generally assigned to chrysocolla in that it shows the Chilean mineral to be an acid metasilicate of copper. I venture to express the belief that a careful reëxamination of other blue chrysocollas may lead to similar results.

Central High School,
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THE PURIFICATION OF WATER SUPPLIES BY THE USE OF HYPOCHLORITES.

By WILLIAM PITT MASON, M.D.

(Read April 23, 1909.)

There is no question but those of us who have taken ground as opposed to the "disinfection" of water by "bleach," hypochlorite of sodium, or other similar substances, must change our position. The experimental work in France and England; the improvement of the water of Bubbly-Brook at the Chicago Stock Yards, and, above all, the remarkable results secured by the Jersey City Water Supply Co., when operating upon the entire municipal supply of Jersey City, suffice to silence opposition to what may be termed the most recent purification method of to-day.

It is true that some years ago the "Woolf" process was proposed, whereby an electrolyzed salt solution was employed for addition to either sewage or water; and still further back the "Webster" plan was advocated; but none of the hypochlorites was exploited in the systematic and exhaustive manner that has been recently accomplished, nor has the smallness of the "dose" that will accomplish efficient treatment ever been suspected. Let the following facts speak for themselves:

Lake water was treated with increasing "doses" of "bleaching-powder" equivalent to the amount of available chlorine indicated. It was then allowed to stand three hours in the dark, shaken and sowed for "total count" of bacteria.

Dose of Bleach.		
Grains per Gallon.	Parts per Million.	Bacteria per c.c.
0	0	102,900
3/100	.51	410
1/20	.85	320
1/10	1.70	175
1/8	2.12	100
1/4	4.25	95
1/2	8.50	45

Numerous similar sowings were made and even lower counts of residual germs were found.

Upon examining waters charged with pure cultures of *Bacillus coli communis,* and others contaminated with fresh fecal material of human origin, no gas-forming bacteria of any kind were found alive in any instance after the use of even the smallest dose of "bleach" shown above.

Other experimenters have reached similar conclusions with still smaller doses of "available chlorine." The most satisfactory test of the process, however, is the practical one of treating the entire municipal supply daily furnished to Jersey City. The dose there used during the month of December, 1908, averaged approximately .03 grain available chlorine per gallon and has since been materially reduced. While using the above amount the daily counts of bacteria for the month were:

RAW WATER.

Maximum	1,600
Minimum	240
Average	559

TREATED WATER.

Maximum	30
Minimum	0
Average	2.7

No part of this minute dose of hypochlorite reaches the consumer and protection against pathogenic organisms appears to be assured.

It is not expected that the process will take the place of filtration because it does not aid in improving the physical appearance of a water, but as an adjunct to a filter plant there can be no question of its usefulness in times of emergency, and it can surely be depended upon to render a reasonably polluted water safe for domestic purposes, and do it at a moderate price.

It goes without saying that the hypochlorite of sodium, obtained by electrolyzing a solution of common salt, can be substituted for the bleaching powder whenever local conditions allow of its cheap manufacture. The effect upon bacterial life is the same.

RENSSELAER POLYTECHNIC INSTITUTE,
TROY, N. Y.,
April, 1909.

THE DETONATION OF GUN COTTON.

By CHARLES E. MUNROE.

(*Read April 23, 1909.*)

In the use of gun cotton in mines or torpedoes, advantage is taken of the discovery of Mr. E. O. Brown that gun cotton, which is completely saturated with water, may be detonated by the detonation of "dry" gun cotton in direct contact with it, for it thus becomes possible to secure a large margin of safety for the naval vessels carrying gun cotton torpedoes by keeping the major portion of this cargo completly saturated with water so that it is immune from the danger common to the powerful nitric esters of accidental explosion through so-called "spontaneous combustion" while it is still available for use at any moment as a detonating charge. It is, in fact, as my experimental demonstrations have shown, an even more efficient rupturing or shattering explosive than the same volume of dry gun cotton is, the explanation of this increased efficiency being found in the increased density, and therefore rigidity, imparted to the porous mass through its interstices becoming filled with water.

The blocks, or discs, as thus used, contained, on the average, 35 per cent. of water. In practice, this wet charge, in the service torpedo, was fired or detonated by four 2-inch discs of "dry" gun cotton, or its equivalent in ½-inch discs or blocks, which was known as the priming charge. As used the term "dry" meant air-dry and necessarily referred to a variable condition dependent upon the atmospheric conditions which obtained at any time and the exposure of the primer to these conditions.

It is desirable to know how reliable this system is and what assurance may be placed in it. This may to a degree be determined by ascertaining how much moisture the priming disks may contain and yet detonate the wet gun cotton with certainty. It was not feasible to carry this out on the large scale with charges of the mag-

nitude used in torpedoes, nor did it seem necessary to the solution of the problem that this should be done. As I have previously shown, such tests may be made upon single unconfined blocks or disks of wet gun cotton, resting upon rigid iron supports, the evidence of complete detonation being found in the impressions left upon the iron support with which the explosive is in contact, and this method was resorted to in this instance.

Number of Experiment.	Dry Primers, Grains.	Wet Primers, Grains.	Per Cent. of Moisture.	Results.
1	336	374	10.16	Detonated
2	293	330+	11.21	"
3	342	387	11.63	"
4	337	382	11.78	"
5	346	393+	11.96	"
6	330	376	12.23	Failed
7	294	337	12.77	Detonated
8	292	335	12.84	Failed
9	317	365	13.15	"
10	294	339	13.27	"
11	301	348	13.51	"
12	294	341	13.78	"
13	305	355	14.09	Detonated
14	292	340	14.12	Failed
15	286	336	14.88	"
16	289	340+	15.00	"
17	286	337	15.13	Detonated
18	289	343	15.74	Failed
19	287	341	15.84	"
20	295	351	15.95	"
21	279	333+	16.22	"
22	322	386+	16.58	"
23	293	353	17.00	"
24	313	378	17.20	"
25	301	364	17.31	"
26	320	390	17.95	"

In carrying out the tests steam-dried blocks of gun cotton, which were to be used as priming charges, were carefully weighed. They were then immersed in water for awhile and again weighed, the increase in weight showing the amount of water that had been absorbed by each priming block. Immediately after weighing, and before evaporation from the primer could take place, these primers were placed, one after the other, upon blocks of saturated "wet" gun cotton and fired by the service detonator, containing 35 grains of mercuric fulminate, in the usual manner. The results of the trials are set forth in the following table, in which they are arranged

in the ascending order of the percentage of water present in the priming blocks, although of necessity the experiments were made on the primers as taken from the water and containing varying quantities of this substance.

The results show that detonation was effected in every case in which the primer contained less than 12 per cent. of moisture, but that this also occurred in experiments number 7, 13 and 17, in which the primers contained 12.77, 14.09 and 15.13 per cent. of water respectively. These irregularities may be explained by the irregularity of absorption of water by these blocks, owing to a lack of regularity of porosity in them, for we can readily understand that if the centers of these blocks, about the detonator holes, were more highly compressed and therefore denser than a portion of the remainder of each block, while the total water absorbed by the block would be represented by the percentages given, yet the center might remain dry enough to respond to the effect of the detonation of the mercuric fulminate in the detonator, and thus determine the detonation of the whole primer and also of the wet gun cotton block with which the latter was in contact. This criticism may also apply in a reverse manner to the primers containing less than 12 per cent. of water, but the likelihood of such an excess of water about the detonator hole as to prevent the detonation of the primer becomes the more remote the less the total percentage of water present. It is true that these vagaries may have sometimes been due to variations in the detonators used, but this factor was eliminated in these experiments, so far as seemed possible, by previous severe tests of the detonators. Admitting all of these possibilities, it would still seem reasonable to conclude from these experiments that primers containing less than 12 per cent. of water, when fired by means of a detonator containing 35 grains of mercuric fulminate may be relied upon, so far as the moisture content is concerned, to detonate wet gun cotton with which they are in contact.

THE GEORGE WASHINGTON UNIVERSITY.

THE COMPARATIVE LEAF STRUCTURE OF THE STRAND PLANTS OF NEW JERSEY.

(PLATES II–V.)

BY JOHN W. HARSHBERGER, PH.D.

(Read April 23, 1909.)

In the *Proceedings of the American Philosophical Society* for last year (XLVII: 97–110. 1908), I presented the results of my study of the leaf structure of the sand dune plants of Bermuda. So many points of interest developed in the course of that investigation, that I undertook a study of the leaf structure of the characteristic species growing along the sea shores of New Jersey. This investigation was also in part a continuation of those previously conducted on the geographic distribution of the New Jersey strand flora begun in 1892 and continued down to the present year.

PHYTOGEOGRAPHY OF THE STRAND.

The strand flora of New Jersey comprises several well-marked phytogeographic formations, namely, the sea beach formation, the dune formation, the thicket formation and the salt marsh formation. The sea beach formation comprises those plants which grow on the middle and upper beaches, the lower beach being wave swept. The typic plants of this formation are *Cakile edentula, Ammodenia (Arenaria) peploides, Salsola kali, Euphorbia polygonifolia, Cenchrus tribuloides, Ammophila arenaria, Xanthium echinatum, Atriplex arenaria, Sesuvium maritimum, Strophostyles helvola* and *Solidago sempervirens.* The dunes of New Jersey consist of windblown silicious sand and occur at greater or less height along the entire coast from Sandy Hook to Cape May, while back of them occur salt marshes which fringe the open bays, or river channels. The character plants of the New Jersey dunes are the marram

grass, *Ammophila arenaria* (Plate II, Fig. 1), which anchors the sand, the beach pea, *Lathyrus maritimus, Hudsonia tomentosa* (Plate II, Fig. 2), *Solidago sempervirens, Euphorbia polygonifolia,* the wax berry, *Myrica carolinensis,* poison ivy, *Rhus radicans,* beach plum, *Prunus maritima,* and Virginia creeper, *Ampelopsis* (*Parthenocissus*) *quinquefolia.*

The thicket formation (Plate III, Fig. 3), as it exists on the New Jersey strand consists in some places entirely of shrubs, in other places, it is composed of trees which form a characteristic forest growth. The vanguard of this thicket consists of cedars, *Juniperus virginiana,* which never rise above the level of the dunes among which they grow. Young trees in the dune hollows are spire-shaped, but upon the tops reaching the general level of the dune summits, they become flat-topped and incline in a direction opposite to the prevailing wind. The following species enter into the thicket formation throughout coastal New Jersey: *Juniperus virginiana, Q. nana* (=*Q. ilicifolia*), *Q. lyrata, Q. obtusiloba* (=*Q. minor*), *Q. phellos, Pinus rigida, Sassafras officinale, Diospyros virginiana, Nyssa sylvatica, Acer rubrum, Magnolia glauca* (=*M. virginiana*), and as secondary species in the form of shrubs *Rhus copallina, Prunus maritima, Vaccinium atrococcum, V. corymbosum, Myrica carolinensis* and such lianes as *Vitis Labrusca, V. æstivalis, Ampelopsis quinquefolia, Rhus radicans* together with a host of herbaceous species mentioned in former papers.

Geographically there are two regions of salt marshes along the New Jersey coast, viz., that of the northern coast, north of the head of Barnegat Bay and that of the south and middle coast along Barnegat Bay and southward to Cape May. The salt marshes on the north coast are confined to the shores of the rivers which manage to cut their way through the sand barriers in order to reach the ocean. They are, therefore, comparatively circumscribed in area and are, as a rule, narrow strips bordering the tidal channels of the seaward-flowing streams. The salt marshes, however, south of Bay Head widen out into extensive expanses of flat, featureless character cut by numerous tidal channels (Plate III, Fig. 4). Those north of Barnegat Inlet nowhere exceed a mile in width, while south

of Barnegat Inlet the salt marshes widen out until in places they may be from two to four miles wide cut by thoroughfares into characteristic marsh islands. The tidal channels are generally bordered throughout the two regions by the tall salt grass, *Spartina stricta maritima,* back of which occur *Spartina patens, Juncus Gerardi* and *Distichlis spicata.* On the flat marsh only flooded to a depth of an inch or two at high tide occur *Limonium carolinianum, Plantago maritima, Aster subulatus, Suæda linearis, Distichlis spicata, Chenopodium rubrum, Pluchea camphorata, Salicornia herbacea, S. mucronata, Tissa marina* and *Gerardia maritima,* while *Baccharis halimifolia* and *Hibiscus moscheutos* occur in salt marsh soil which is never flooded with each rising tide. *Eleocharis pygmæus* forms floating mats in the sloughs surrounded by salt marsh at Sea Side Park (Plate III, Fig. 4).

Ecologic Factors.

The ecologic factors must be considered under two heads, because the strand plants are found growing under two distinct environmental conditions. The typic strand plants display various xerophytic adaptations to their growth in the silicious sand of the sea beaches and sand dunes. The factors which are instrumental in producing the xerophytic structures which the leaves of strand plants show may be considered to be the following: (1) The permeability of the sand to water, so that after a rain the surface layers dry out. (2) The action of strong winds that blow across the sandy beaches increasing the rate of transpiration materially and carrying sand, which is directed against the plant, as a sandblast. (3) The relatively dry soil and the increased transpiration by wind action necessitates the adoption of structures which will enable the plant to conserve its water supply. (4) The reflection of light from the sand and the foam-crested breakers beyond is influential, but this influence is not so marked as in Bermuda where the sand is a white coral sand and presumably the sunlight is reflected to a greater extent. (5) The illumination from above has also been effective, but perhaps not so much so as in Bermuda. (6) The action of the salt spray blown inland by the wind is

effective in modifying the structure of the beach and dune plants, but is hardly active upon the species of the thicket formation. (7) Formerly it was supposed that the plants of the sea beaches had to contend against the salt content of the soil, but Kearney has shown that the amount of salt in the sand of sea beaches is a negligible quantity, as many agricultural soils of the interior contain relatively more salt than the seashore sand.

While the beach plants have, therefore, according to the researches of Kearney, been removed from the list of true halophytes, nevertheless the typic salt marsh species show marked halophytic adaptations and belong to the second category of strand plants. The most potent factor which is here influential is the presence of free salt water about the bases and roots of the salt marsh plants. It was pointed out by Schimper that any considerable amount of salt in the cell sap is detrimental to the plant and that here we have the probable cause of the characteristic halophytic modifications which aim, therefore, at decreasing the amount of water transpired. To this Warming replied, that even if transpiration were diminished, slowly, but surely, an amount of salt would accumulate in the plant which would prove its destruction. On the other hand, Warming proposed that the protective contrivances against strong transpiration are necessary in halophytes, because absorption of water from a salt solution is slow and difficult and what water the plant had absorbed must be conserved in order to provide against desiccation, while the plant is absorbing enough water to replace that lost in ordinary transpiration. Sodium chloride in solution is known to have strong plasmolytic properties, removing water from living cells when subjected to its action. Ganong has found that the root hairs of *Salicornia herbacea,* a typic halophyte, can endure a 100 per cent. sea water without plasmolysis; those of *Suæda maritima* 80 per cent.; those of *Plantago maritima* 70 per cent.; while those of *Atriplex patulum* withstood 50 per cent. sea water. Graves found that the root hairs of *Ruppia maritima* could stand a 105 per cent. sea water with occasionally very slight plasmolysis, while with 110 per cent. sea water, it was rather slow, but finally distinct. So that the group of halophytes with which we are here dealing

possesses great power of resisting the action of sodium chloride in solutions as strong, as sea water. This is reflected in their structure.

Structural Adaptations.

These will be treated as applicable to the strand plants, as one category, and to the salt marsh plants as the other.

Strand Plants.—The leaf adaptations to light are found in the increased number of palisade layers, their presence on the upper and under sides of the leaves and their arrangement, so that the central part of the leaf becomes palisade throughout. When both leaf surfaces are equally illuminated, the leaf may be termed isophotic, when unequally illuminated, diphotic. Diphotic leaves which show a division into palisade and spongy parenchyma have been called by Clements diphotophylls. Isophotic leaves are of three types, viz., the staurophyll, or palisade leaf; the diplophyll, or double leaf; the spongophyll, where the rounded parenchyma cells make up the bulk of the leaf in cross-section. Succulent leaves are those developed for water storage and to some extent the presence of latex provides against desiccation. The depression of the stomata, the development of a thick cuticle, the presence of a hypodermis of thick-walled cells, the presence of hairs and the formation of air-still chambers by a folding of the leaf tissue are all structures which assist in the regulation of transpiration. The following is a classification of the different leaf structures with reference to the strand plants which illustrate such adaptive arrangements.

Thick Cuticle: *Ammophila arenaria, Quercus obtusiloba, Ilex opaca.*

Thick Epidermis: *Baccharis halimifolia, Ampelopsis quinquefolia, Euphorbia polygonifolia, Cakile edentula.*

Hypodermis Present: *Ammophila arenaria.*

Two or More Rows of Palisade Cells: *Lathyrus maritimus, Strophostyles helvola, Ampelopsis quinquefolia, Quercus obtusiloba, Vitis Labrusca, Ilex opaca, Baccharis halimifolia.*

Stomata Depressed (slightly): *Euphorbia polygonifolia, Lathyrus maritimus, Ilex opaca, Hudsonia tomentosa;* (deeply) *Ammophila arenaria, Lathyrus maritimus* (Sea Side Park), *Atriplex hastata, Vitis Labrusca.*

Succulent Leaf: *Cakile edentula, Solidago sempervirens, Atriplex hastata.*

Leathery Leaf: *Lathyrus maritimus, Ampelopsis quinquefolia, Quercus obtusiloba, Xanthium echinatum, Ilex opaca.*

Wiry Leaf: *Ammophila arenaria, Cenchrus tribuloides,*

Hairy Leaf: *Ammophila arenaria, Xanthium echinatum, Quercus falcata, Hudsonia tomentosa, Vitis Labrusca, V. æstivalis, Cenchrus tribuloides.*

Leaf Surface Papillate: *Euphorbia polygonifolia.*

Leaf Becoming Erect in Sun Position: *Strophostyles helvola, Lathyrus maritimus, Euphorbia polygonifolia* (leaf blade folding along the midrib).

Overlapping Leaves: *Hudsonia tomentosa.*

Latex Tissue: *Euphorbia polygonifolia.*

Raphides: *Vitis æstivalis, V. Labrusca.*

Sphærocrystals: *Atriplex hastata, Ilex opaca.*

Idioblasts: *Cenchrus tribuloides.*

Diphotophyll: *Euphorbia polygonifolia, Strophostyles helvola, Lathyrus maritimus, Ampelopsis quinquefolia, Quercus obtusiloba, Q. falcata, Vitis Labrusca, V. æstivalis, Ilex opaca, Baccharis halimifolia.*

Diplophyll: *Cakile edentula, Atriplex hastata* (Belmar), *Xanthium echinatum.*

Staurophyll: *Atriplex hastata* (Normandie), *Solidago sempervirens.*

Spongophyll: *Hudsonia tomentosa, Cenchrus tribuloides.*

Salt Marsh Plants.—The majority of the salt marsh species studied showed two marked characteristics, namely, succulency and wiriness. The following is a categoric presentation of the structure of their leaves. The smooth character of the leaves will be noted with the exception of *Gerardia maritima, Hibiscus moscheutos, Pluchea camphorata* which grow back in the interior of the salt marshes away from the tidal water.

Thick Cuticle: *Spartina stricta maritima* (lower surface).

Thick Epidermis: *Distichlis spicata* (lower surface), *Aster*

subulatus, Suæda linearis, Gerardia maritima, Limonium carolinianum.

Hypodermis Present: *Spartina stricta maritima, Distichlis spicata.*

Two or More Rows of Palisade Cells: *Aster subulatus, Limonium carolinianum, Gerardia maritima, Hibiscus moscheutos.*

Stomata Depressed: *Spartina stricta maritima, Tissa marina, Plantago maritima, Aster subulatus, Chenopodium rubrum.*

Hairy Leaf: *Gerardia maritima, Hibiscus moscheutos, Pluchea camphorata.*

Succulent Leaf: *Tissa marina, Plantago maritima, Aster subulatus, Suæda linearis, Chenopodium rubrum, Limonium carolinianum.*

Wiry Leaf: *Spartina stricta maritima, Distichlis spicata, Gerardia maritima.*

Leathery Leaf: *Hibiscus moscheutos, Pluchea camphorata.*

Diphotophyll: *Aster subulatus* (drawing is upside down), *Limonium carolinianum, Gerardia maritima, Hibiscus moscheutos.*

Diplophyll: *Tissa marina, Suæda linearis.*

Staurophyll: *Chenopodium rubrum.*

Spongophyll: *Plantago maritima, Pluchea camphorata.*

Detailed Srtucture of the Leaves.

The sections of the leaves which were studied were made freehand with a razor, stained with Bismarck Brown and mounted for permanency in Canada Balsam. The drawings of these sections were made by the use of the micro-projection electric lantern, so that in every case (32 leaves) the sections were enlarged to the same extent and therefore the drawings were made on the same scale. The details of leaf structure and those of the stomata were made from a microscopic study after the main features of the leaf structure had been located by the micro-projection lantern. In this way the relative size of each leaf section is maintained in the thirty-two detailed drawings presented in the accompanying two plates (Plates IV and V). The drawings of stomata were not made to scale.

Strand Plants.—The typic sand-inhabiting plants will be described first.

Ammophila arenaria (Plate II, Fig. 1; Plate IV, Figs. 1, 1*a*, 2, 2*a*).—The beach, or marram grass, is a perennial species with firm, running rootstocks, which on account of their length, and the readiness with which the rigid, leafy culms arise from them serve to bind the drifting sand. The one-flowered spikelets are crowded in a long spike which reaches its full development in August and September. The leaves are involute and in a Wildwood-grown specimen (Plate IV, Fig. 1) examined microscopically the lower epidermis consisted of small cells with thick outer wall reinforced by 2–3 rows of hypodermal sclerenchyma isolated in patches below the vascular bundles. The upper epidermis, covering the grooves and the ridges, is irregular owing to the development of short, sharp-pointed hairs like canine teeth, which help to form an air-still chamber. The stomata are much depressed and level with the lower wall of the epidermal cells (Plate IV, Figs. 1*a* and 2*a*). Beneath the epidermis, hypodermal sclerenchyma is found in several well-marked rows. The chlorenchyma occupies a position on either side of the veins which run lengthwise. In the leaf section of a plant gathered at South Atlantic City (Plate IV, Fig. 2), the lower epidermis is reinforced by a continuous band of hypodermal sclerenchyma. The hypodermal sclerenchyma in the upper part of the ridges is more abundant than in the Wildwood-grown plants. A section of a leaf from a plant that grew on the low dunes of Belmar had comparatively little hypodermal sclerenchyma and in every way it was a thinner leaf than those from the Wildwood and South Atlantic City specimens.

Euphorbia polygonifolia (Plate IV, Figs. 3 and 3*a*).—The seaside spurge is a prostrate, spreading herb, with oblong-linear leaves slightly cordate, or obtuse at the base and folding together along the midrib. The most conspicuous feature in the section is the large latex canals which fairly fill the center of the leaves and are marked by large surrounding, secreting cells. The upper epidermal cells are papillate, and the lower epidermal cells are without these papillæ, but the outer wall is thickened. The stomata are slightly

depressed (Plate IV, Fig. 3*a*). The loose parenchyma is prominent, as also the single row of palisade cells.

Strophostyles helvola (Plate IV, Figs. 4 and 4*a*).—This annual, trailing, leguminous herb has ovate to oblong-ovate leaflets with a more or less prominent rounded lobe toward the base. The flowers produced from June to September are greenish-white to purplish. In the hot sun, the leaflets assume hot-sun positions. The cells of the upper epidermis are thin-walled with the outer wall slightly thickened. Two well-marked rows of palisade cells are present, while the stomata are at the surface (Fig. 4*a*). The loose parenchyma is clearly seen and the lower epidermis consists of thin-walled cells.

Lathyrus maritimus (Plate IV, Figs. 5, 5*a*, 7, 7*a*).—The beach pea is a perennial, stout, trailing plant, as it occurs on the dunes of New Jersey. The coarsely toothed stipules are nearly as large as the leaflets, which are 6–10 in number, ovate-oblong. The leaflets assume hot-sun positions, especially those near the surface of the sand. The flowers are large and purplish, appearing from June to September. The epidermal cells on both the upper and lower surfaces of the leaflets are thin-walled with a slightly thicker outer wall, rounded, almost chain-like in arrangement. The loose parenchyma is compact and there are two rows of palisade cells.

Cakile edentula (Plate II, Fig. 1; Plate IV, Figs. 6 and 6*a*).—The sea rocket is a fleshy annual growing on the upper sea beaches and in clumps on the sand dunes (Plate II, Fig. 1). Its fleshy leaves are obovate, sinuate and toothed. The epidermal cells are large with outer walls slightly thickened, while the parenchyma cells are large and directed vertically with the exception of a few central cells, so that the leaf structure is that of a typic diplophyll. The stomata are at the surface (Fig. 6*a*). The xerophytic structure is, therefore, seen in the fleshy character of the leaf and in the arrangement of the internal parenchyma cells.

Solidago sempervirens (Plate IV, Figs. 8 and 8*a*).—The seaside golden-rod is a smooth, stout plant 0.3–0.5 m. high. The somewhat fleshy leaves are entire, lanceolate, slightly clasping; the lower ones are oblong-lanceolate, obscurely triple-nerved and all of the leaves

are vertical or nearly so. The contracted panicle of heads appears from August to November. The thin-walled, upper epidermal cells are approximately square in outline in the transverse view, only the outer wall being somewhat thickened. Chlorenchyma cells almost homogeneous, are directed vertically, hence the leaf is a staurophyll.

Atriplex hastata (=*A. patula* var. *hastata*) (Plate IV, Figs. 9, 9*a*, 10 and 10*a*).—The orache is an erect, or spreading, stout plant and at least the lower leaves are broadly triangular, hastate, often coarsely and irregularly toothed. The upper and lower epidermal cells are large, thin-walled. The chlorenchyma of similar elongated cells extends from the upper to the lower surface, so that the leaf is a typic staurophyll. Large sphærocrystals are present in the parenchyma cells of the leaf and the guard cells of the stomata are considerably sunken beneath the surface (Figs. 9*a* and 10*a*). The leaves of the specimen from Belmar were somewhat thinner than those from Normandie and the chlorenchyma cells were more rounded.

Hudsonia tomentosa (Plate II, Fig. 2; Plate IV, Figs. 11, 11*a*). —The dunes are in many places covered with this heath-like plant (Plate II, Fig. 2), which is an important sand binder, as it grows in dense clumps. The small awl-shaped leaves are oval or narrowly oblong and are close-pressed and imbricated, covered with a downy tomentum. The epidermal cells of the leaves are thin-walled and covered with slender, sharp-pointed hairs with a smooth cuticle. The hairs are so numerous on both sides of the leaf, that they act effectively in controlling transpiration. The guard cells of the stomata are only slightly depressed (Fig. 11*a*).

Cenchrus tribuloides (Plate IV, Figs. 12, 12*a* and 12*b*).—The sand bur grass branches extensively and sometimes has the trailing habit. The blades are more or less involute, owing to the presence of bulliform cells. The upper epidermal cells are marked by crystalline idioblasts (Fig. 12*a*) in an elongated form like the cystoliths in the leaf of the rubber plant, *Ficus elastica*. The epidermal cells on the under side of the leaf where the sclerenchyma occurs are terminated by short cusp-like spines. The guard cells (Figs. 12*b*

and 12*c*) are not sunken below the general surface. The upper epidermal cells are large, irregular in size and rounded. The lower epidermal cells are irregular and consist of bulliform with spiny hair cells opposite the leaf veins. The leaf exhibits a typic spongophyll structure.

Xanthium echinatum (Plate IV, Figs. 13 and 13*a*).—The cockle bur has broadly ovate, cordate leaves and the whole plant is rugose, especially the leaf surfaces. The upper and lower epidermal cells are thin-walled and provided with stout, projecting, multicellular hairs. The palisade cells extend through the leaf except a narrow row of cells near the center. Although this leaf has been classified as a diplophyll, yet it might with equal propriety be called a staurophyll.

Quercus obtusiloba (Plate IV, Fig. 14).—The post oak is a common tree in the pure dune sand of the New Jersey coast. The leaves are obovate in outline, 1–2 dm. long, the usually fine lobes spreading, the middle pair of sinuses are deep, wide and obliquely rounded at the bottom of the lobes. The leaves are leathery, thick and shining with scattered hairs above, densely gray, or yellowish hairy beneath. The epidermal cells are small with thick cuticle and the lower surface shows the presence of multicellular hairs. The palisade rows number from two to three and the loose parenchyma is compact. The leaf is a typic diphotophyll.

Quercus falcata (Plate IV, Figs. 15 and 15*a*).—The Spanish oak has leaves which are prolonged into a more or less scythe-shaped lobe with the under leaf surfaces grayish-downy or fulvous. The upper epidermal cells are large and thin-walled, as are also the lower epidermal cells. From the lower surface, a lot of compound hairs project, the tines of which are straight, sharp-pointed cells. The stomata are not depressed and a single row of palisade cells is present, so that the leaf is a typic diphotophyll.

Vitis Labrusca (Plate IV, Figs. 16 and 16*a*).—The northern fox grape has large leaves which are entire, or deeply lobed, slightly dentate. They are rusty-wooly beneath. The vines begin their growth on the forest trees, and as the sand drifts in around them, the grape vine branches grow out in a prostrate manner over the

surface of the dune sand. The upper epidermal cells are thin-walled. The palisade layer consists of one row of cells and below it we find cells here and there containing a mucilaginous substance in which are imbedded raphides, or needle-shaped crystals. The loose parenchyma is prominent and the lower epidermal cells are thin-walled and from them grow out long unicellular, sharp-pointed, straight hairs which become matted together. This hairy covering is of use in the regulation of transpiration. The guard cells are somewhat depressed (Fig. 16*a*) and the leaf exhibits a typic diphotophyll structure.

Vitis æstivalis (Plate IV, Fig. 17).—The summer grape has large unlobed or more or less deeply and obtusely 3–5-lobed leaves, provided with a very wooly and mostly rust-red, or tawny-flocculent tomentum. This tomentum does not appear in the section, because the wooly hairs are mostly attached to the veins beneath and merely cover the epidermal surface between, so that a section which does not include the veins does not show the hairy covering of the under side of the leaf. The upper and lower epidermal cells are thin-walled and in the single palisade layer are found cells containing a mucilage in which are imbedded raphides, or needle-shaped crystals of calcium oxalate.

Ilex opaca (Plate III, Fig. 3; Plate IV, Figs. 18 and 18*a*).—In the reproduced photograph (Plate III, Fig. 3), the holly is found associated with *Sassafras officinale, Rhus radicans* and *Solidago sempervirens*. The leathery oval, spiny-margined holly leaves have an upper epidermis of small cells covered with an extremely thick cuticle. Three rows of palisade chlorenchyma are present and a loose parenchyma, as an area of considerable width with large intercellular lacunæ. The lower epidermis consists of thick-walled cells and the guard cells, if sunken, are only depressed to the extent of the thick cuticle. Sphærocrystals are present in some of the cells of the third palisade row of cells. A tree with spineless-margined leaves was formerly found on the dunes at South Atlantic City. The leaf is a typic, xerophytic diphotophyll.

Baccharis halimifolia (Plate IV, Figs. 19 and 19*a*).—The leaves of the groundsel bush are thickish, vertical and obovate to wedge-

shaped, coarsely toothed, or the upper leaves entire. The upper epidermal cells have a considerably thickened outer wall with a warty cuticle. Stomata occur on both leaf surfaces with their guard cells not depressed below the surface. Palisade chlorenchyma of two rows of cells extends to the centrally placed bundles of the leaf and it is rather openly arranged. The loose parenchyma with large spaces shows its cells generally directed in a vertical manner, suggesting a staurophyll, but the bifacial structure is clearly recognizable, so that we may classify the leaf as a diphotophyll. The lower epidermis of thin-walled cells shows a roughened outer cell wall surface.

Ampelopsis quinquefolia (Plate IV, Figs. 20 and 20*a*).—The Virginia creeper with a compound leaf with five leaflets is an element of the dune flora of New Jersey. It begins to ascend forest trees, and if these trees are surrounded by drifting sand, the vine spreads out over the sand surface. In other places, it grows on the surface of the dunes and helps to bind the wind-blown sand. The sand-grown plants have leathery leaves in which the upper epidermal cells are compact with the outer wall thickened and its surface rugose. Two rows of palisade cells may be found and the loose parenchyma occupies the other half of the leaf below the midrib and the veins. The stomata are not sunken, and the leaf is a typic diphotophyll.

Salt Marsh Plants.—The plants of this group are all of them true halophytes, and at the conclusion of the description which follows of the histology of their leaves, a comparison will be drawn between their leaf structure and that of the leaves of the sand strand plants previously described.

Spartina stricta maritima (=*S. glabra*) (Plate V, Figs. 21 and 21*a*).—The salt marsh grass is a tall species 0.6–2.4 m. high, leafy to the top and growing along the shore in pure salt water. The leaves are 5–7 dm. long, 1–1.5 cm. wide, usually flat, but sometimes involute. The lower epidermal cells are strongly cuticularized, and where the bundles occur they are reinforced with hypodermal sclerenchyma. The upper leaf surface is raised into ridges, which are covered with small cuticularized epidermal cells without hairs, while

the stomata found near the bottom of the grooves have their guard cells depressed below the surface (Fig. 21*a*). Bulliform cells are absent. The chlorenchyma is radially arranged on each side of the bundles, while the parenchyma sheath surrounding the bundles also contains some chlorophyll.

Distichlis spicata (Plate V, Fig. 22).—The spike grass, or alkali grass, occurs in the salt marshes along our eastern coast from Nova Scotia to Texas, along the Pacific coast and in alkaline soil through the interior to the Rocky Mountains and southward in alkali sinks into Mexico. The culms are 1.5–6 dm. high and the leaf blades are often conspicuously distichous, rigidly ascending. The lower epidermis consists of thick-walled cells, the outer wall being especially thick. The upper epidermis consists of projecting hair cells with thick walls resembling in shape a canine tooth and found covering the ridges down into the grooves between, so that an air-still chamber is formed. The bundles are surrounded with thick-walled cells, which are in turn engirdled by a parenchyma sheath, while the rest of the leaf section is occupied by chlorenchyma.

Tissa marina (=*Buda marina, Spergularia salina, Spergularia marina*) (Plate V, Figs. 23 and 23*a*).—The sand spurrey is a much-branched, procumbent, or suberect, annual herb more or less distinctly fleshy. The leaves are linear and terete surrounded with large, thin-walled, epidermal cells with several rows of palisade parenchyma directly beneath and completely surrounding the large thin-walled parenchyma cells of the interior. The stomata are depressed below the surface (Fig. 23*a*). A typic, succulent diplophyll.

Plantago maritima (=*P. decipiens*) (Plate V, Figs. 24 and 24*a*).—The seaside plantain has linear to nearly filiform leaves 1–10 mm. broad, indistinctly ribbed and fleshy. The epidermal cells are large thin-walled with the outer wall slightly thickened with minute projecting points. Palisade cells are entirely absent and large parenchyma cells with chlorophyll fill the interior, extending to the bundles placed near the center. The stomata are not depressed, or only slightly so (Fig. 24*a*).

Aster subulatus (Plate V, Figs. 25 and 25*a*).—The leaves of the salt marsh aster are linear-lanceolate and pointed. The upper

leaf surface (turned upside down in Fig. 25) consists of thick-walled epidermal cells beneath which are two rows of illy defined, palisade cells, while beneath the palisade are compactly-placed, rounded chlorenchyma cells extending to the loose parenchyma cells with large intercellular spaces. The lower convex, epidermal surface is composed of thick-walled cells, the outer wall being especially thick. The guard cells are depressed the thickness of the outer cell wall (Fig. 25*a*).

Limonium carolinianum (Plate V, Figs. 26 and 26*a*).—The sea lavender has thick, stalked, radical leaves from which the much-branched scape arises, bearing small, lavender-colored flowers. The epidermal cells are large, thin-walled, but the outer wall is slightly thicker than the other walls. Two rows of palisade cells are found and a spongy parenchyma of rounded cells. The stomata are at the surface (Fig. 26*a*).

Suæda linearis (Plate V, Fig. 27).—The sea blite is an erect, or ascending, fleshy, saline plant 2–9 dm. high. Its leaves are narrowly linear and acute. The epidermal cells are thin-walled, but project as rounded knobs the tops of which are thickened, The chlorenchyma, as palisade tissue, is found equally developed on the upper and the lower surfaces, while the interior cells are large and rounded parenchyma elements. A typic diplophyll.

Gerardia maritima (Plate V, Figs. 28 and 28*a*).—This marsh plant is a slender, erect, branching annual, somewhat fleshy with linear, obtuse leaves. The upper leaf epidermis has two kinds of hairs, straight, projecting ones and low, dome-shaped hairs, the terminal cells containing a brown substance. The palisade chlorenchyma forms two well-defined rows with compact spongy parenchyma beneath. The lower epidermis consists of thin-walled cells with superficial guard cells (Fig. 28*a*).

Chenopodium rubrum (Plate V, Figs. 29 and 29*a*).—The coast blite has a much-branched, angled stem with thickish, triangular, lanceolate leaves tapering below into a wedge-shaped base and above into an acute point, sparingly and coarsely toothed. The epidermal cells are thin-walled, with the outer wall curved outward. The vascular bundles are centrally placed, while the elongated, rounded

chlorenchyma cells are aligned as palisade. Sphærocrystals are abundant and the guard cells are depressed considerably (Fig. 29*a*).

Hibiscus moscheutos (Plate V, Figs. 30 and 30*a*).—The swamp rose-mallow is a tall perennial with showy rose pink, pink or white flowers and alternate ovate, pointed leaves, sometimes 3-lobed with a downy, whitened, under surface. The upper epidermal cells are comparatively thin-walled, while the lower epidermis of thin-walled cells is characterized by clusters of long, straight, pointed hairs densely matted together. There are two rows of palisade cells beneath which is found spongy parenchyma, while the guard cells of the stomata are slightly raised above the general epidermal surface (Fig. 30*a*). The leaf is a diphotophyll.

Pluchea camphorata (Plate V, Figs. 31 and 31*a*).—The salt marsh fleabane is an annual with oblong-ovate, or lanceolate, slightly petioled leaves. The stem and leaves are somewhat glandular, emitting a strong, or camphoric, odor. The epidermal cells are thin-walled and multicellular hairs abound on both surfaces. The stomata are not depressed (Fig. 31*a*). The chlorenchyma in the form of rounded cells is not differentiated into palisade and spongy parenchyma. A spongophyll.

Eleocharis pygmæa (=*E. nana*) (Plate V, Figs. 32 and 32*a*).—This small sedge formed small floating masses on the surface of the salt water sloughs at Sea Side Park (Plate III, Fig. 4). The bristle-like culms are tufted at the base and in section show large air canals, or lacunæ, surrounded by small thin-walled parenchyma cells. The bundles are reduced in size and the epidermis is composed of small thin-walled cells. A typic hydrophyte adapted to an halophytic existence.

General Conclusions.

We have listed twenty plants among those which grow on the sand strand and eleven which may be considered to be typic salt marsh species. Out of the twenty strand plants four are succulent, or twenty per cent., while out of eleven salt marsh species six are succulent, or over fifty per cent., so that the salt marsh species are preponderantly succulent. Only three of the salt marsh plants studied have epidermal hairs, while nine of the strand plants

are hairy. Eleven of the strand species are diphotophylls, and of these six have two rows of palisade chlorenchyma. Only four of the salt marsh species are diphotophylls, and each of them has two palisade rows. Reference to the classification of sand strand and salt marsh species given above will enable the student to pick out other differences existing between the sand strand and the salt marsh species, as regards their leaf structure.

Bibliographic Notes.

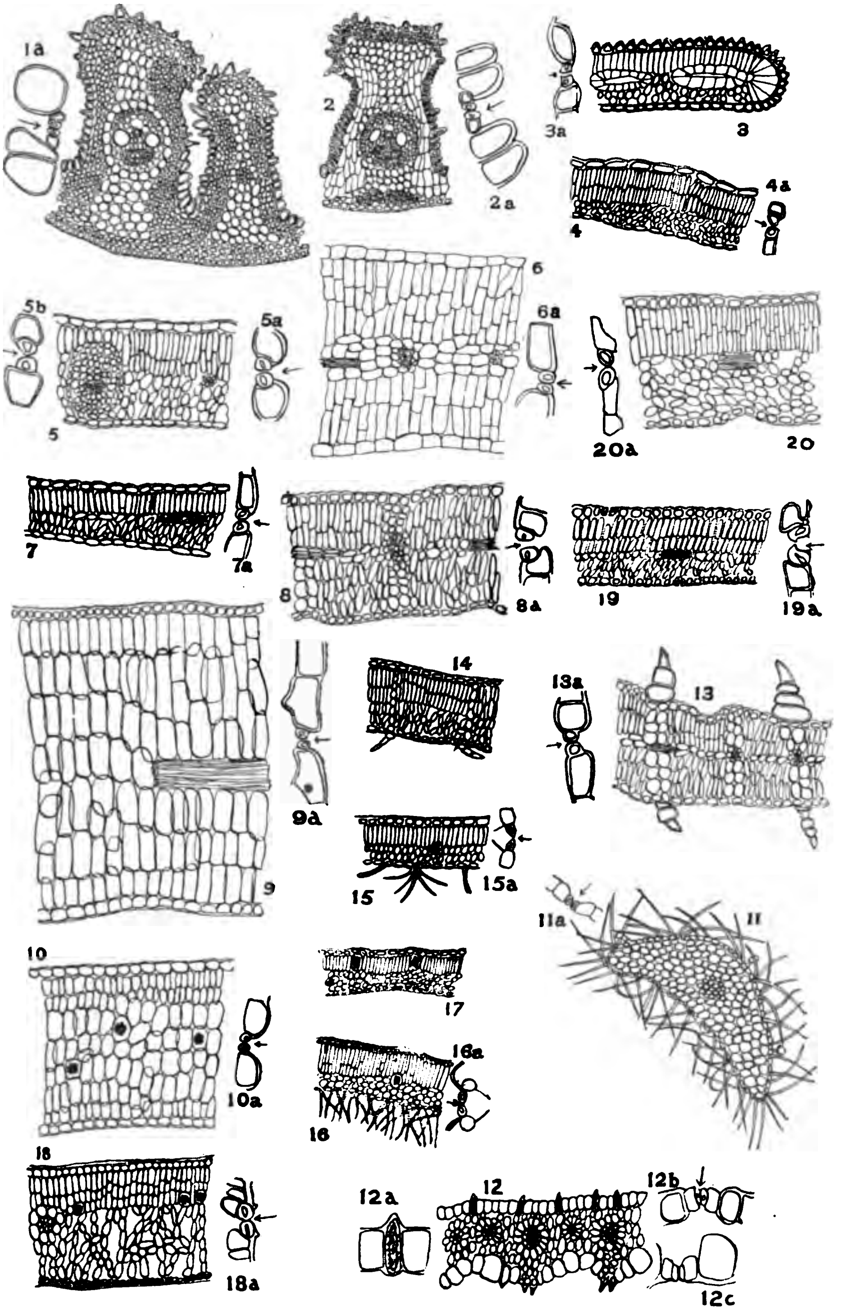
Little has been done in America to study the influence of environment upon the internal structure of plants, but a start has been made and it is only a matter of time when a large amount of important data will have been collected for comparison and generalization. As bearing upon the study of the sea strand vegetation may be mentioned the following papers. Kearney has discussed in his paper, "The Plant Covering of Ocracoke Island: A Study in the Ecology of the North Carolina Strand Vegetation" (Contributions U. S. National Herbarium, V: 280–312), the histologic structure of plants found upon Ocracoke Island as sand strand and salt marsh species. In this paper the following plants concern us: *Spartina stricta, Tissa marina, Solidago sempervirens, Aster subulatus* and *Baccharis halimifolia.* In a second paper, "Report on a Botanical Survey of the Dismal Swamp Region" (Contributions U. S. National Herbarium, V: 484–509), under anatomic notes, Kearney discusses the leaf structure of some selected plants. None of these plants actually concern this paper, except *Pluchea fœtida* and *Baccharis halimifolia.* Edith Schwartz Clements, in a thesis submitted to the faculty of the Graduate School of the University of Nebraska for the degree of doctor of philosophy (June, 1904), gives a useful historic résumé of the study of leaf structure from an ecologic standpoint and also considers in a detailed manner the structure of about three hundred species collected in the Colorado foothills and mountains of the Pikes Peak region of the Rocky Mountains with reference to the surrounding physical factors, which were determined by careful instrumental readings. Lastly, Harshberger, in a paper noticed above, discusses the leaf structure of some seventeen

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.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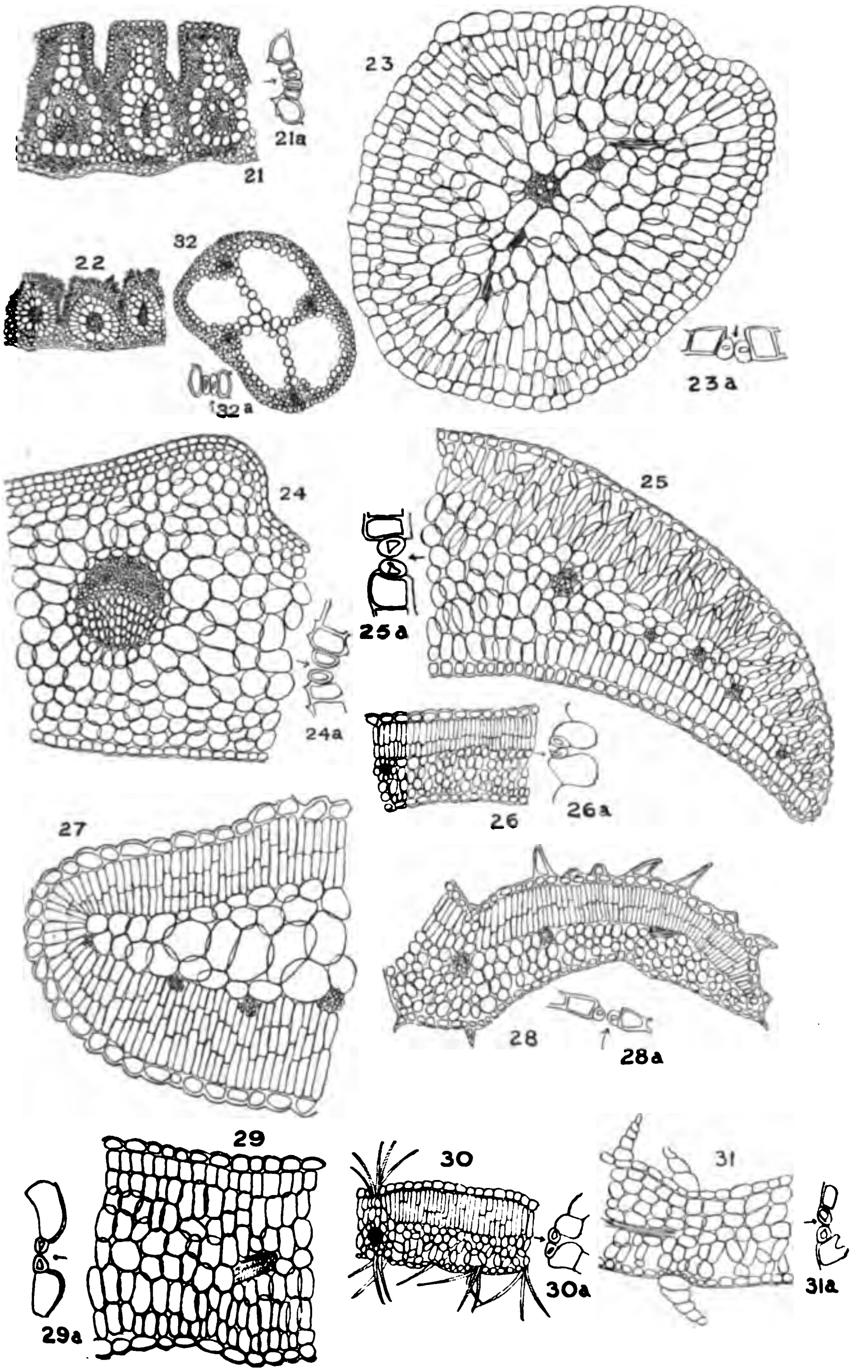
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species of Bermudan plants with relation to the environmental factors of the sand dunes upon which the plants grew. In this paper a short bibliography of the principal papers is given.

Explanation of the Plates.

In Plate II, Fig. 1, is shown the frontal sea dune at Sea Side Park covered with the marram grass *Ammophila arenaria* and a large clump of *Cakile edentula,* while in Fig. 2 is represented the crest of the frontal dune covered with marram grass, back of which occur the waxberry *Myrica carolinensis* and the clumps of *Hudsonia tomentosa.*

The photograph reproduced in Plate III, Fig. 3, represents the thicket formation at South Sea Side Park composed of *Ilex opaca, Sassafras officinale, Rhus radicans* and *Solidago sempervirens.* In Fig. 4, Plate III, is represented a slough with floating rafts of *Eleocharis pygmæa.* The twenty enlarged figures with details of stomata, shown in Plate IV, represent the structure of the leaves of the sand strand plants of New Jersey, while the twelve figures and stomata enlargements represent the leaf structure of typic salt marsh species (Plate V).

THE DESTRUCTION OF THE FRESH-WATER FAUNA IN WESTERN PENNSYLVANIA.

(Plate VI.)

By DR. A. E. ORTMANN.

(*Read April 23, 1909.*)

It is generally known that the advance of civilization in a country is connected with a retreat and the disappearance of the indigenous fauna. This has been observed most distinctly in those parts of the world which have been settled by the white man in more recent times, and in many cases we have positive records with reference to the killing and crowding out of the original inhabitants of the country, belonging to the animal kingdom; yet these records chiefly concern the more highly developed forms of life (mammals or vertebrates in general), which preëminently attract attention.

But there are many other forms of animal life, chiefly among the invertebrates, which suffer the same fate. Such cases generally are not noticed, but students particularly interested in such groups often have reason to deplore the disappearance of interesting creatures, which used to be abundant.

The present writer, in connection with his duties as curator of invertebrate zoölogy at the Carnegie Museum, has made it one of his chief objects to study and to preserve records of the fresh-water fauna of the northeastern section of the United States, and first of all, of the country lying in the immediate vicinity of Pittsburgh. This region belongs to the drainage of the upper Ohio and of Lake Erie, and it is well known that originally a very rich fauna was present here, a fauna which forms part of the great fauna of the interior basin, eminently rich in all forms of fresh-water life. It is also a well-known fact that on account of the progress of civilization in western Pennsylvania, on account of its industrial and commercial development, and all the various features of "improve-

ments" connected with it, the fresh-water fauna has deteriorated, has become poor, and in many cases extinct. Yet it is not realized how far this process has advanced, and to what extent the fresh water of this region has become unfit for the indigenous life. The present paper has the object to record the present state of things in this respect, and to point out which rivers and creeks are in such a state that they do not offer any more the required conditions for animal life, and which are yet in a good or fair condition. It may be remarked that all facts collected here have been ascertained by the writer in person, in the course of his studies during the last five years. All streams recorded on the map accompanying this paper (Plate VI) have been visited by the writer, and collections of their invertebrate fauna and observations on their vertebrate fauna have been made, wherever such was still present: but in many cases his efforts were in vain, and life had entirely disappeared in many streams. The blue color on our map tells a pitiful story, pitiful not only from the standpoint of the scientific man, but also with reference to the question of utility. For we must not forget that the original fauna of the fresh water forms part of the "natural resources" of the country. In many cases the direct economic value, chiefly of the fresh-water invertebrates, is not very apparent; but considering the fact that all forms of life in an ecological community are mutually dependent upon each other, we realize that the more important forms (mussels, fishes and aquatic mammals) cannot be preserved, unless the creatures which furnish the necessary conditions for their subsistence are also preserved. Thus the destruction of our fresh-water fauna forms a chapter of the book on the destruction of our natural resources, a record which is not at all to the credit of the nation.

I. The Fresh-Water Fauna.

The part of the fresh-water fauna which has chiefly been studied by the writer is, as has been stated, the *invertebrates*. However, during his investigations, he kept his eyes open for *vertebrate* life, and among the latter it is chiefly the *fishes* to which he paid attention. He did not make systematic collections of the fishes, and thus

he cannot give positive information as to the presence or absence of particular species of them. But the question of their existence in general in the different streams is easily settled, in fact this is the most conspicuous criterion by which people generally judge the condition of a stream—whether there is "good fishing" or not.

However, the presence of fishes in a stream does not always indicate that the latter is in good shape. The condition of the streams, as we shall see below, often changes during the season; it is bad in dry weather, but improves when there has been copious precipitation. The fishes are most apt to take advantage of such temporary improvement on account of their great power of locomotion (vagility); in fact, many fishes migrate more or less regularly up or down stream, and thus may be present at certain seasons in parts of our water-courses, which are barren in other seasons.

Other vertebrates are of minor importance. Among the mammals we should mention the muskrat (*Fiber zibethicus*). This animal is fairly abundant everywhere, but, as might be expected, tends to disappear, where its food disappears. The latter consists only in part of invertebrates (mussels for instance), while in another part it is vegetable (roots of aquatic plants, and also various parts of land plants). Thus it is understood that the pollution of a stream does not render the existence of muskrats impossible. And further, the bad condition of the water does not harm the animal directly, since it is an air-breathing form. The fact that the muskrat is decidedly less frequent in polluted streams is probably due to the fact that the pollution is greatest in the vicinity of larger settlements, where there is greater danger for them by being hunted by man.

Of the reptiles, water-snakes (*Natrix sipedon* and *leberis*) and turtles should be considered. As regards the former, it is a general rule that they disappear from polluted streams, and very likely not on account of the direct influence of the water upon their body, but on account of the destruction of their food—fish and crawfish. The turtles live in part upon animal, in part upon vegetable food; they are found, at present, in numbers only in streams which are in good condition, and have disappeared, more or less, in those with

polluted waters; this, however, at least in certain species, is apparently due also to direct extermination by man. The soft shell turtle (*Aspidonectes spinifer*) is a good example; it used to be present almost everywhere, but it has been exterminated practically in the Ohio, the lower Allegheny, the Monongahela and Youghiogheny. It is still present, for instance, in the clear waters of the upper Youghiogheny, the upper Allegheny, in Lake Erie, etc.

Among the amphibians, frogs and toads do not prefer the streams; they rather are pond and lake forms, and, besides, inhabit the water only at certain seasons. They do not seem to be very susceptible to the quality of the water, since they are air-breathing animals, and, consequently, are still abundant, although certain species show a tendency to become rare. Thus the bullfrog is met with in numbers only in the northwest of the state, where clear streams, ponds and lakes prevail. Yet in this case, extermination by man has surely played a part.

Of the Urodela, the smaller salamanders and newts do not inhabit in large numbers the rivers and creeks, but prefer rather the mountain streams, the ponds and lakes, where generally the conditions are yet good. Thus there does not seem to be an appreciable reduction of their number. The two large salamanders, the hellbender (*Cryptobranchus allegheniensis*) and mud puppy (*Necturus maculosus*) surely are influenced by the pollution, yet not directly, but by the destruction of their food. They seem to be the last members of the fresh-water fauna which disappear, and are occasionally found where there is no other permanent life. (Hellbenders were frequent in the Conemaugh River at New Florence, Westmoreland Co. Nothing but a few fish and crawfish were at this locality, which apparently came from a clear tributary.)

The most important forms of invertebrates, which I have studied more closely, are the crustaceans and the mollusks. Occasionally I have collected fresh-water sponges, worms, bryozoans, but of all these we may say that they disappear very soon after the stream has become polluted. They are found only in such waters which contain an abundance of other life.

The crustaceans of the genus *Cambarus* (crawfishes) are rather susceptible, and we may say that generally the pollution of a stream

destroys them. They seem to be slightly more resistant than the Unionidæ (see below), but their presence in a polluted stream is in many cases clearly due to a restocking of the stream, by immigration from a clear tributary. The crawfishes are rather vagile, and possess the power to migrate, although less so than the fishes. There surely is the possibility for them to take advantage of a temporary improvement of the condition of a stream.

The most important group, with reference to the matter in question, are the bivalve mollusks of the family Unionidæ, the fresh-water mussels or river-clams. They are the most reliable indicators of the pollution of a stream. Being rather sedentary, living on the bottom of the rivers, breathing water, they are easily influenced by the deterioration of the water. Of all the more important groups of our fresh-water fauna, they die first, and after they have been exterminated, it is exceedingly difficult to restock the stream on account of the complex life history of the young mussels. It is known that the young Unionidæ are transported and dispersed by fishes, but in a polluted stream the fishes have also disappeared, and even in a case of a temporary recovery of a stream, in times of a high stage of the water, if there should be a restocking with young mussel-fry, the latter will surely be killed during the next low stage, when the pollution again is concentrated. In this respect the Unionidæ surely are worse off than the fishes and crawfishes.

Of other mollusks, the gasteropods belonging to the family Pleuroceridæ (*Pleurocera, Goniobasis, Anculosa*) should be mentioned. They are generally absent in polluted rivers, but have been found surviving, together with crawfishes, in parts where Unionidæ were entirely, and the fishes for the greater part gone (Allegheny River in southern Venango County). Other mollusks, which are air breathing (genera *Lymnæa, Planorbis, Physa*) are more resistant, and this is especially true of *Physa*, which represents in certain instances the only remaining life in certain rivers. But there also seems to be a limit to its power of endurance, and in very badly polluted streams also *Physa* is absent.

Thus we can establish, in a rough way, a certain succession for the disappearance of our fauna.

The first sign of pollution of a dangerous character in a stream

is given by the disappearance of the Unionidæ, and, generally, this fauna is irreparably lost. Close upon this follows the disappearance of the fishes, yet in times of recovery of the rivers (at high-water stages), fishes reappear, coming from tributaries, etc., which have acted as preserves, and this may go on indefinitely as long as the river is recovering again at times, since the fishes possess a high power of locomotion (as we shall see below, the construction of dams in a river puts an end also to this). Crawfishes stand it a little longer than fishes, but they also disappear finally, and the temporary restocking of a stream takes place only in a limited degree.[1] With the crawfishes, or soon after them, the Gasteropods of the family *Pleuroceridæ* are driven out. When the process has reached this stage, the higher forms of life, which subsist on these various forms are compelled to abandon the stream: *tailed Batrachians, Snakes,* and part of the *Turtles.* Finally, only *Lymnæa, Planorbis* and *Physa,* and the muskrat survive. Of these, *Physa* disappears last, while the muskrat may stay indefinitely, being not entirely dependent upon animal or aquatic food.

II. The Causes of the Destruction of the Fauna.

A. Direct Extermination by Man.

A number of fresh-water animals are directly killed by man, and thus disappear in streams, the character of which has not been changed unfavorably for life. This is true in the first line for the *fishes.* Fishes, forming part of human food, are sought for everywhere, and in consequence of the increase of the population necessarily must be decimated in number. Yet a complete destruction of the fish life hardly has ever been brought about by man alone, chiefly so, if the fishing is carried on under the restrictions put upon it by law. The fact is that there are many places where "fishing is good," and where fishermen freely avail themselves of this chance, but where fishes are still abundant (upper Allegheny River, for

[1] It happens sometimes that restocking of the lost territory is done by a different species. Thus in the Mahoning Creek at Punxsutawney, Jefferson Co., and in Slipperyrock Creek at Branchton, Butler Co., the original species, which was destroyed, was *Cambarus obscurus,* and, subsequently, *C. bartoni* entered the creek.

instance). This is not so in certain remote streams, but not on account of the legitimate pursuit of the sport, but in consequence of the illegal destruction of the fishes. The worst is the dynamiting of the streams which, of course, can be carried out safely only in such places where the fish warden is likely not watching. I can name at least one stream, in which this has had serious consequences: *Raccoon Creek* in Beaver County, and here it is done, as I have been informed, by parties that come over the state line from West Virginia and Ohio, and that have no right whatever to fish in our waters. The fish warden cannot be on the spot all the time, and the farmers of the region are powerless to stop the abuse, and thus Raccoon Creek, which is physically in good condition, and which used to teem with fish life, has been spoiled. For the dynamiting kills all fishes, old and young indiscriminately, and must be regarded as the most contemptuous way of wanton destruction.

I do not doubt that it is resorted to in other parts (I heard of one case in *Deer Creek,* Allegheny County, not far from Pittsburgh), yet, of course, since it is executed by the guilty parties only under rigorous precautions, in order that they may not be caught by the authorities, such cases generally escape detection.

There is only one other group of fresh-water animals which is of direct value to man (if we disregard the muskrat, which is hunted for its pelt, and some turtles, which are eaten). These are the fresh-water mussels (Unionidæ). For food they are not much sought, but the occasional occurrence of pearls in them makes them valuable. In Pennsylvania pearl fishing is not much practiced, yet I know that certain individuals hunt for pearls in mussels along the Allegheny River in Armstrong County, and once I came across a party of three, hunting pearls in the Ohio in Beaver County. These people were from somewhere down the Ohio in the state of Ohio or West Virginia, and it was indeed a sight to look upon the wholesale destruction carried on by them.

In general we may say that by the direct action of man our fresh-water fauna, chiefly that of the fishes, has suffered a good deal, but the complete extermination has not been brought about by it in any stream. Fishing might go on in the usual way, under the established legal restrictions, and our fish fauna will survive indefi-

nitely. If we further consider the fact that the state is trying to restock our streams artificially, this might entirely counterbalance the losses caused by the fisherman, and thus we may say that fishing alone would never destroy our fish fauna.

B. Pollution of Streams.

The worst damage to our fauna is done by the *pollution* of the streams, that is to say, by the discharge into them of substances which are directly injurious to life. This is connected directly with our commercial and industrial progress, and the damage done by it is irreparable, unless there is some radical change in the way of the disposal of the industrial refuse, which at present is generally allowed to run directly into the nearest stream.

The most widely distributed pollution of a stream is by *sewage* from the larger towns and cities. This in itself is rather innocent. I am not discussing the deterioration of the waters from a sanitary standpoint; but with regard to animal life in our rivers, sewage does not seem to be harmful; on the contrary, certain forms (fishes, crawfishes, mussels) seem to thrive on it. Only in a few cases I have seen sewage so concentrated (certain small runs in the city of Pittsburgh), that animal life is killed.

Much more dangerous sources of pollution are given by our *coal mines*. Under this head I unite all sources of pollution, which are connected with the mining of coal, with the coking process, and with the steel industry. This kind of pollution is very widely distributed in the western part of the state. It is a process which charges the water of our streams with certain acids, which, when they reach a certain degree of concentration, directly kill the life.[2] A stream polluted by "mine water" is easily recognized (when clear) by the peculiar bluish-green color of the water, and by a peculiar rusty-red deposit upon its bottom.

Another source of pollution is furnished by the *oil wells* and the oil industries. The simple working of an oil well already yields injurious matter: during the drilling of the well invariably *salt water* is pumped up, and the *oil* itself is capable of destroying life, if present in excess, and forming, at low stages, a deposit upon the

[2] See Stabler H., Water Supply and Irrigation Paper no. 186, 1906, p. 5.

bottom of a creek. But the worst are the *oil refineries,* which discharge into the water chemicals which are utterly destructive to life.

These are the two most important sources of the pollution of our streams: *coal* and *oil.* In addition, there are others, which are more or less local, yet may become quite important in certain sections. These are various industrial establishments, such as *glass factories, china factories,* different kinds of *chemical factories, wood-pulp mills,*[3] *saw mills, tanneries,* etc. There are certain sections of the state, for instance the region of the headwaters of the Allegheny and of Clarion River, where establishments of this kind are the chief source of contamination.

It is not my intention here to treat of the chemical side of the process, because it is rather complex, and needs careful investigation by experts. This investigation is rendered more difficult, since in most of our streams it is not one cause, which contributes to the pollution, but several, often all of them, which contribute their share in a particular stream.

Finally, a last cause of destruction of life should be mentioned, which, however, is not connected with a deterioration of the quality of the water. This is the *damming up of certain rivers.* This has been done most extensively in the Monongahela River, and in a part of the Ohio below Pittsburgh. The dams and locks have been built for the advantage of the shipping interests, producing a more uniform level of the water, permitting navigation all the year round. By this process the rivers, which originally possessed a lively current, with riffles, islands, etc., have been transformed into a series of pools of quiet, stagnant water, and this change has driven out certain forms of life. It is most destructive to mussels, most of which require a lively current. Dams also prevent free migration, for instance of fishes, and thus they must be an obstacle to the natural restocking of the rivers in periods of high water.

[3] See Phelps, E. B., Water Supply and Irrigation Paper no. 226. 1909.

III. Sketch of the Present Condition of Our Rivers.

(See map, plate VI.)

1. *The Ohio River Below Pittsburgh.*

At Pittsburgh, the two main rivers, *Allegheny* and *Monongahela,* unite to form the *Ohio.* As we shall see below, both the *Allegheny* and *Monongahela* are as badly polluted as they possibly could be, and, consequently, it is not astonishing that the *Ohio* immediately below Pittsburgh is also in a deplorable condition. In addition, it is dammed up, this "improvement" extending down to dam No. 6 at Vanport (below Beaver) in Beaver County. Generally, there is not much life in this part of the Ohio. Fishes are found occasionally, during high water, due to some migration, probably from farther down the river, but even this has been rendered difficult or even impossible in consequence of the perfection of the dams (dam No. 6 was finished and put in operation toward the end of 1907). There are crawfishes in this part of the river, but they are disappearing fast. Unionidæ have disappeared long ago. There was a colony of them in the left branch of the Ohio at Neville Island, Allegheny County, up to 1904; during that year, however, they died out, and in 1905 the last living one was found there.

Farther down, below dam No. 6, conditions improve. This is a very interesting and important fact. Although the Ohio collects most of the polluted water of the western section of the state, and although it is in a very bad condition below Pittsburgh, it loses its bad qualities, at least in part, about thirty miles farther down. Since there are only two important tributaries along this part of its course, Chartiers Creek and Beaver River, both of them also badly polluted, this improvement of the water cannot be due to dilution alone, but it is evident that some of the injurious substances in the water must be removed from it, and very probably by precipitation upon the bottom of the river. We shall observe indications of this process elsewhere, and shall discuss its significance below. Here it is sufficient to point out, that at present (1908) the condition of the Ohio below dam No. 6 is good or fair, life being not only possible, but abundant in it, all the way down to the state line at Smith's

Ferry. This is shown first of all by the abundance of Unionidæ in this part of the Ohio; in fact, here are found the most favorable localities for them known to me in western Pennsylvania. It seems that in 1907 these conditions extended a certain distance farther up; at any rate, in that year I found evidence of the presence of Unionidæ in the Ohio at Beaver (the stage of the water was not low enough for proper investigation). But since the completion of dam No. 6 this is all over now, and if there should be life in the pool above dam No. 6 it will have disappeared by this time, at least most of it.

Moreover, there are indications that the fauna in the Ohio below Vanport is already suffering. There are at least two tremendous banks, consisting chiefly of dead shells (with many living ones among them) in the river, one at Industry, the other at Shippingport. Since dead shells are dissolved rather rapidly, these masses indicate a recent dying of mussels on a large scale. And further, it is very remarkable that among the living shells collected by myself there are hardly any young individuals. It seems to me that, while the old and tough ones (some of them probably ten years old and older) are able to stand the poor condition of the water, the latter is too much for young and delicate ones, so that there is no new generation growing up. This, of course, would be the first step toward the final destruction of the mussels in this part of the river, and the destruction of the other forms of life then will also be accomplished in due time.

2. *The Smaller Tributaries of the Ohio.*

There is a group of streams in Greene and Washington Counties, running westward through the panhandle of West Virginia into the Ohio. These are (from south to north): *Pennsylvania Fork of Fish Creek, Wheeling Creek, Buffalo Creek, Cross Creek, Harmons Creek.* They are all clear creeks, only *Harmons Creek* and *Cross Creek* are slightly polluted by mine water, but not much damage has been done yet. They are all rich in aquatic life. I have not visited *Wheeling Creek* in Pennsylvania, but I know it in West Virginia, above Elm Grove, near Wheeling, where it is in good condition.

Raccoon Creek, which empties from the south into the Ohio

below Vanport, is in very good condition for most of its length, only way up at its sources, in Washington County, it is slightly polluted by mine water. This creek used to be rich in all forms of life, and is yet so here and there, but, as has been said, its fish fauna has greatly suffered in consequence of illegal fishing.

At the point where the Ohio leaves the state a very beautiful tributary flows into it from the north—*Little Beaver Creek.* This was, and partly is, a model stream with regard to all forms of fresh-water life. Yet in 1908 there were, in its upper parts, near New Galilee, in Beaver County, signs of pollution, in this case in consequence of new oil wells being drilled in the vicinity. Salt water and oil was discharged into the creek, and the fauna (chiefly the mussels) indicated distinctly the deteriorating effect by their diseased condition and by the frequency of shells which had died recently. This may be only a temporary effect, and if there is no additional pollution, conditions may remain favorable.

Immediately below Pittsburgh, *Chartiers Creek,* coming from the south, empties into the Ohio. It is hopelessly polluted by the coal mines and oil refineries in Allegheny and Washington Counties. There is no life whatever in this creek: the last traces are known to have existed in it as late as 1900, when a few Unionidæ were collected in it for the Carnegie Museum. The condition of Chartiers Creek is now beyond repair.

3. *The Beaver River Drainage.*

Beaver River flows into the Ohio from the north at Beaver, Beaver County. It is utterly polluted in its whole length, up to the point where it is formed by the confluence of Mahoning and Shenango rivers. The source of the pollution is situated on the Shenango River, along its last two miles, in and below Newcastle, Lawrence County. The steel mills and various other establishments furnish a tremendous amount of injurious refuse draining into the river, and rendering it entirely unfit for life. This state of affairs has been brought about during the last ten years, for in 1898 the fauna of the river was very rich at Wampum, Lawrence County, as is shown by collections preserved in the Carnegie Museum.

Connoquenessing Creek, flowing into the Beaver from the east, is another badly polluted stream. In this case there are various causes of pollution, but the chief one is the refuse from the glass works at Butler, Butler County. In the lower parts of Connoquenessing Creek traces of life are yet present, but in a few years everything will be gone. Above Butler, the creek is in a fair condition. Of its tributaries, *Glade Run* is polluted by oil well products. *Brush Creek* is good, and also *Slipperyrock Creek* in its lower course. The latter is an example of the natural clearing of the water, for in its upper parts, in northern Butler County, it is in a very bad condition, polluted by mine water. In this case dilution of the pollution apparently plays an important part, for at least two of its tributaries, *Wolf* and *Muddy Creeks,* are in good condition. In *Wolf Creek* the effect of plain sewage is distinctly seen by the fact that the fish- and mussel-fauna are favored by it—the Unionidæ attain an unusual size just below the point where the sewage from Grove City, Mercer County, goes into the creek.

Of the two rivers which form the Beaver, *Mahoning River* is, as has been shown by Leighton,[4] badly polluted in the state of Ohio at Alliance, Warren, Niles and Youngstown. Yet in Pennsylvania, in its lower parts, it is rich in life. We again have to deal here with the natural clearing process of the water. At Hillsville, where the Mahoning enters our state, it is in poor condition, yet there is some life. Then comes a dam at Edinburg, and below this dam conditions are much better. In fact, the fauna is rich, and continues so till the river joins the Shenango. In this case, there are no important tributaries along this stretch, and the clearing of the water cannot very well be attributed to dilution.

The *Shenango River* above Newcastle is in good condition all the way up to its sources, and so are its tributaries, *Neshannock Creek, Pymatuning Creek* and *Little Shenango River.* Only at and below Sharon and Sharpsville, in Mercer County, some pollution goes into the Shenango from the steel mills, but it has not had much effect yet. However, the damage is bound to increase, and I am afraid in a few years the effect will be noticeable. At the present

[4] See Leighton, M. O., U. S. Geol. Surv. Water Supply and Irrigation Paper no. 79, 1903, p. 133.

time these creeks are in splendid condition at many points, and this is preëminently the case, as regards the fish fauna, in Neshannock Creek.

4. *The Monongahela Drainage.*

We may say that of the Monongahela drainage by far the greatest part is utterly polluted, chiefly by mine water.[5] The *Monongahela* and its chief tributary, the *Youghiogheny,* drain the most important coal regions of the state, and there are, in this whole region, only a few streams left which have clear water. They are the following: *Ten Mile Creek* and *Dunkard Creek* in Washington and Greene Counties, yet the *South Branch of Ten Mile Creek* became polluted in the spring of 1908 by the bursting of an oil pipeline near Waynesburg, Greene County. *Dunkard Creek* is yet splendid in every respect. *Cheat River* is clear, but there are only two or three miles of it in the state, and on its right banks, at Cheat Haven, a small run empties into it, which brings a great amount of mine water from the coke-ovens at Atchinson, killing everything along its right banks.[6]

The *Youghiogheny* is in a fair condition above Connelsville, Fayette County, and *Indian Creek,* one of its tributaries, is very good (trout stream). However, the Youghiogheny has improved from Confluence down. For at this place it receives a badly polluted tributary, *Casselman River,* which brings mine water from the mines in southern Somerset County. The Youghiogheny above Confluence, south into Maryland, is very clear and pure.

For the rest, all the more important creeks tributary to the Monongahela system, in Washington, Fayette and Westmoreland Counties, are polluted by mine water. This is especially true in the cases of *George* and *Redstone Creeks,* draining the Uniontown district, *Jacobs Creek,* coming from the Mount Pleasant and Scottdale mines, and, worst of all, *Turtle Creek,* with its tributary, *Brush Creek,* which drain the coal fields of Westmoreland County.

[5] Leighton, *ibid.*, p. 126 ff. This condition obtained already in 1898, see Rhoads, S. N., in *Nautilus,* 12, 1899, p. 133.

[6] The condition of the Cheat below Parsons, Tucker Co., W. Va., is dreadful, it being polluted by the refuse from a wood pulp mill. But it improves farther down.

5. *The Allegheny Drainage.*

(*a*) *The lower Allegheny, from Oil City and Franklin* (*Venango County*) *downward,* is first badly polluted, then it improves, and is again polluted to a very considerable degree. The chief source of pollution are the oil refineries at Oil City and Franklin. The injurious substances discharged into the river at these two places are simply amazing, and render the river entirely unfit for life; for thirty miles and more below there is not a mussel, not a crawfish, nor a fish able to live in this water. Then a gradual improvement begins in southern Venango County (pond snails, *Physa* and *Goniobasis* are present, also crawfishes begin to appear), and in northern Armstrong County conditions become almost normal. In spite of some additional pollution going into the river at Kittanning and Ford City (china factories), the good condition continues down to the point where the *Kiskiminetas River* discharges its mine water into the Allegheny from the left side. This destroys life on the left banks of the Allegheny, but conditions continue favorable on the right banks into Allegheny County, till we reach Natrona and Tarentum. Here additional pollution comes in in the shape of salt water (salt works at Natrona) and the refuse of various mills, and this goes on all along the river down to where it unites with the Monongahela at Pittsburgh. Here the Allegheny is utterly polluted, and we have here possibly the greatest variety of pollution of any of the streams in the state.[7]

(*b*) *The Smaller Tributaries of the Lower Allegheny River.*—Of the following smaller tributaries of the lower Allegheny, the condition is known to the writer. On the right side, *Pine Creek,* in Allegheny County, is polluted more or less, chiefly by oil wells, but its headwaters are in a fair condition. *Deer Creek* and *Bull Creek* are rather good. *Buffalo Creek,* running along the boundary line of Butler and Armstrong Counties, is in very good condition, and contains an abundance of life. On the left side is *Puketta Creek,* forming the boundary of Allegheny and Westmoreland Counties, which also is in rather good condition.

(*c*) *The Kiskiminetas Drainage.*—As has been stated above, the

[7] See Leighton, M. O., *l. c.*, p. 122.

Kiskiminetas River, at its point of union with the Allegheny, is in a fearful condition, the pollution consisting chiefly of mine water from the extensive coal regions of Westmoreland, Indiana, Cambria and Somerset Counties. In fact, we may say, that in almost all of the drainage basin of the Kiskiminetas fresh-water life is extinct.[8] For the main stream, the *Kiskiminetas-Conemaugh,* this is true for its whole length, from above Johnstown in Cambria County downward. The *Loyalhanna River* from Latrobe downward is even worse than the Conemaugh. *Black Lick Creek* and its tributaries, *Two Lick* and *Yellow Creeks,* in Indiana County, are also polluted, and so is *Stony Creek* in Somerset County. There are, in the whole Kiskiminetas drainage, only very few streams possessing clear water and a tolerably well preserved fauna. In Westmoreland County we have a small stream, *Beaver Run,* which is good, and the *Loyalhanna River* above Latrobe contains a rich fauna. In Indiana County *Blacklegs Run* and the upper parts of *Two Lick* and *Yellow Creeks* are in good condition; in the lower part of *Yellow Creek* the fauna was destroyed during 1908. A mine had been opened in 1907 above Homer City, and the mine water discharged into the creek did its deadly work in the summer of 1908, when the stage of the water for the first time after the opening of the mine became so low that the concentration of the pollution was great enough to kill the fauna. On July 23, 1908, the writer personally witnessed the actual destruction of the fauna, and the number of dead and dying fishes seen in Yellow Creek at Homer City was perfectly appalling.

Clear tributaries of the *Conemaugh* are found in the valley between Chestnut Ridge and Laurel Hill: *Tub Mill Run,* for instance, near New Florence, is very good (trout stream). As has been said, *Stony Creek,* in Somerset County, is polluted. Of its tributaries, at least one is in good condition: *Quemahoning Creek;* others have not been investigated, but probably there are more clear streams, chiefly among the headwaters coming down from Laurel Hill and Allegheny Front.

(*d*) *The Great Eastern Tributaries of the Allegheny.*—There are

[8] This is very deplorable in view of the fact that for several fresh species, described by Professor Cope, the Kiskiminetas is the type-locality. No topotypes can be secured any more.

a number of important tributaries, running about parallel to each other from the east to the west into the Allegheny. These are (from south to north): *Crooked Creek, Mahoning Creek,*[9] *Red Bank-Sandy Lick Creek* and *Clarion River. Crooked Creek* is good, indeed, one of the best creeks in the state, yet in the region of its headwaters pollution begins. Near Creekside, Indiana County, new mines have been opened during the last years, and a small tributary discharges here a considerable amount of mine water into Crooked Creek, killing the fauna for several miles. Of course this is bound to become worse in the future. *Mahoning Creek* is utterly polluted, the pollution beginning in the region of Punxsutawney in Jefferson County, and consisting chiefly of mine water. Yet a tributary, *Little Mahoning Creek* in northern Indiana County, has clear water, and correspondingly a rich fauna. *Red Bank-Sandy Lick Creek* also is polluted, chiefly by mine water, which reaches it from the numerous mines existing in its drainage basin. *Clarion River* possibly is one of the worst streams in the state. In the region of its headwaters, in Elk County, it is not mine water, but the refuse of various establishments, such as wood-pulp mills, tanneries, chemical factories (*Elk Creek*), which renders the water unfit for life, and finally *Toby Creek,* emptying into it in the southwestern portion of Elk County, adds its share in the form of mine water. The water of Clarion River, in this region, is black like ink, and retains its peculiar color all the way down to where it empties into the Allegheny (at Foxburg); here the deep blackish brown color of the Clarion River water contrasts sharply with the bluish green water of the Allegheny River.

(*e*) *French Creek Drainage.*—In contrast to most of the streams mentioned so far, *French Creek* and its tributaries are generally clear and possess a wonderfully rich fauna. In fact, this region is one of the best collecting grounds for all forms of fresh-water life. French Creek is fed by several streams draining some of our glacial lakes—*Conneaut Lake* in Crawford County, and *Conneauttee Lake* and *Lake Lebœuf* in Erie County. Also these have clear water and a rich fauna.

(*f*) *The Upper Allegheny.*—Above Oil City, Venango County,

[9] Not to be confounded with Mahoning River in Lawrence County.

the *Allegheny* itself is clear, and also forms a fine collecting ground for the zoölogist. This is especially true for the fish fauna and the fauna of fresh-water mollusks. This good condition continues up to the New York state line in Warren County. Of the tributaries, *Oil Creek* is badly polluted at Oil City, where it falls into the Allegheny, but it is pure at its headwaters. The intermediate parts have not been studied by the writer, so that he cannot name the exact spot where the pollution begins. It is due chiefly to oil refineries. *Tionesta Creek,* in Forest County, is polluted by chemical refuse, at least where it enters the Allegheny; the upper parts have not been investigated. *Brokenstraw Creek,* in Warren County, is in a fair condition, but it belongs to the class of streams which improve during their course: its headwaters are polluted by refuse from tanneries at Cory in Erie County. *Connewango Creek,* in Warren County, which brings the outflow of Chautauqua Lake in New York, is good. The headwaters of the *Allegheny* in McKean and Potter Counties are generally good, but there are some tributaries which are polluted, for instance, *Potato Creek,* in McKean County (polluted by chemical factories). Where Potato Creek falls into the Allegheny it is in a very bad condition, but its size is not sufficient to influence the Allegheny noticeably.

6. *The Lake Erie Drainage.*

Of course *Lake Erie* itself is clear, and contains a rich fauna.[10] In our state there are rather insignificant streams draining into the lake, and they all have pure water, and, as far as they have been examined, a well-preserved fauna. The largest is *Conneaut Creek,* in Crawford and Erie Counties, which has been investigated at several places by the writer, and found to be in good condition. The only other streams known to the writer are *Elk* and *Walnut Creeks,* in Erie County, which are also good.

7. *The Potomac and Susquehanna Drainages.*

Only the headwaters of these streams or their tributaries are situated in western Pennsylvania, and the investigations of the writer are not very extensive in this region.

[10] Our knowledge of the Lake Erie fauna is deplorably poor, chiefly so with reference to the Pennsylvania shores.

Wills Creek, in southern Bedford County, flowing to the Potomac is clear, but it becomes polluted by mine water farther down, at Mt. Savage Junction in Maryland.[11] Several of the headwaters of the *Juniata River,* in Blair County, chiefly in the region of Altoona and Tyrone, are polluted by industrial establishments.[12] The headwaters of the *West Branch of the Susquehanna* and *Clearfield Creek,* in Cambria and Clearfield Counties, are generally polluted by mine water,[13] but there are some clear tributaries. A rather good one is *Cush-Cushion Creek,* in Indiana County. The latter fact is very important, for it is the point of the Susquehanna system which is most advanced in a westerly direction, and marks the most western extension of the Atlantic fresh-water fauna in our state, and it may be said here that Cush-Cushion Creek indeed contains a pure Atlantic fauna, which is in sharp contrast to the western fauna present in some of the tributaries of the Allegheny in the same (Indiana) county, Little Mahoning, Crooked, Two Lick and Yellow Creeks.

Conclusions.

The sketch given above of the present condition of our streams and their fauna is sufficient to give an idea of the tremendous damage done in recent times to our fresh-water fauna. Considering the fact that most of this destruction has been accomplished during the last twenty years; that it is going on continually, and that every year new stretches of the rivers, new creeks are added to the list of the polluted waters, conditions are indeed alarming. I think a glance upon the map accompanying this paper will tell more than any words possibly could.

It is not for the writer to suggest remedies, yet two conclusions are forced upon him. The first is, that with regard to the improvement of the fish-fauna, which is attempted by the State Fish Commis-

[11] See Parker, H. N., Water Supply and Irrigation Paper no. 192, 1907, p. 219.

[12] The quality of the water was poor already in 1904, see Leighton, M. O., in Water Supply and Irrigation Paper no. 108, 1904, p. 65.

[13] Leighton (*ibid.*, pp. 56 and 57) gives in 1904 a rather favorable report on the quality of the headwaters of the West Branch of the Susquehanna (chiefly with regard to drinking purposes). Apparently this has changed to the worse during the last four years.

sion by way of restocking our rivers with game and food fishes, this is a useless undertaking in all those streams which are polluted. Any fishes set free in such waters will not live, or will not stay there, if they can. The other suggestion is furnished by the fact, repeatedly mentioned above, that a river, badly polluted at a certain point, improves in its further course, provided no additional pollution in great quantities is reaching it.[14] This is seen first of all in the Ohio itself in Beaver County, and further in the Allegheny in Armstrong County. Additional examples are Slipperyrock Creek, Mahoning River (Lawrence County), Raccoon Creek, Brokenstraw Creek, Cheat River. This improvement of the waters, of course, is partly due to the dilution of the injurious substances by the addition of clear water from tributaries. But it seems as if this is not the only source of the improvement. In the case of the Allegheny in Armstrong County, the main tributaries (Clarion, Red Bank, Mahoning) themselves are polluted, and the other tributaries are very insignificant in comparison with the size of the Allegheny. This is also seen in the Mahoning River in Lawrence County, which hardly has any tributaries along its course, where the improvement takes place. I think the precipitation of the injurious substances to the bottom plays an important part here. We always have, in polluted streams, some sort of precipitate upon the bottom, most noticeable in streams charged with mine water, where it consists of sulphate of iron,[15] and, consequently, the injurious element must be eliminated, at least to some degree, from the water. This observation suggests a natural remedy—if we could prevent the water charged with polluting substances from reaching our streams directly, that is to say, if we could arrange it that this water is kept in basins or reservoirs for some time, till it has gone through this natural clearing process, and if we allowed only the overflow of these clearing basins to reach our rivers, that is to say, the most superficial strata, which contain the smallest amount of polluting substances,[16] I think this

[14] See Stabler, Water Supply and Irrigation Paper no. 186, 1906, p. 28.

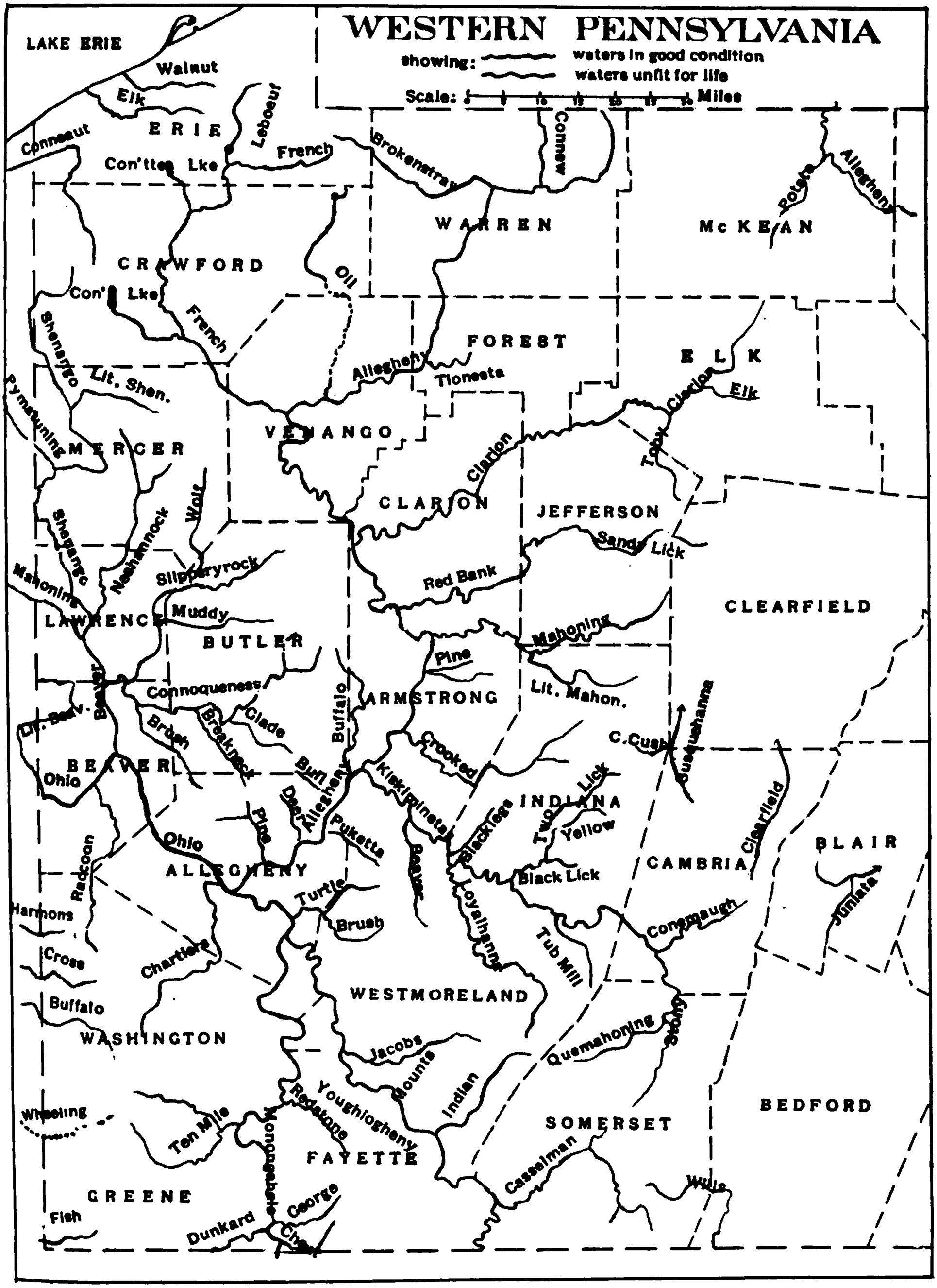
[15] See Leighton, *l. c.*, p. 24.

[16] Of course, the oil from the oil wells floats on the surface, but this floating oil does not do much damage. It is well known that before the discovery of oil in these parts, the Allegheny was famous for the oil floating upon its surface.

would improve conditions considerably. The presence of dams in our rivers or creeks furnishes, to a certain degree, the conditions required for such clearing basins, and we have observed instances (Mahoning River at Edinburg, Lawrence County), where such a dam actually improves the river to a considerable degree. This is also the case, although not so strikingly, with dam No. 6 in the Ohio River. But the trouble is these dams improve the water after much damage has been done already, and are injurious in other respects (see above).

This much, however, should be clear—unless we improve the quality of the water of our rivers, it is impossible to bring back the original condition of their fauna, and attempts to restore our natural resources with regard to the fish fauna, by restocking our polluted streams with fish, will be labor and money thrown away.

CARNEGIE MUSEUM,
PITTSBURGH, PA.


WESTERN PENNSYLVANIA
showing: waters in good condition
waters unfit for life
Scale: Miles
LAKE ERIE
Walnut
Elk
Conneaut
ERIE
Leboeuf
French
Con'ttea Lke
Brokenstraw
Conewango
WARREN
Allegheny
Potato
McKEAN
CRAWFORD
Oil
Con't Lke
French
Shenango
Lit. Shen.
FOREST
Allegheny
Tionesta
ELK
Clarion
Elk
Pymatuning
MERCER
VENANGO
Clarion
Toby
CLARION
JEFFERSON
Wolf
Neshannock
Shenango
Slipperyrock
Sandy Lick
Red Bank
Mahoning
LAWRENCE
Muddy
BUTLER
CLEARFIELD
Mahoning
Beaver
Pine
Connoquenessing
Glade
Breakneck
Brush
Lit. Beav.
Buffalo
ARMSTRONG
Lit. Mahon.
Crooked
C. Cush
Susquehanna
BEAVER
Ohio
Buff
Deer
Allegheny
Kiskiminetas
INDIANA
Two Lick
Yellow
Blacklegs
Clearfield
BLAIR
Pine
Ohio
Puketta
Beaver
Black Lick
Racoon
ALLEGHENY
Turtle
Loyalhanna
CAMBRIA
Juniata
Harmons
Brush
Conemaugh
Cross
Chartiers
Tub Mill
Buffalo
WESTMORELAND
Stony
WASHINGTON
Jacobs
Mounts
Quemahoning
Indian
Wheeling
Ten Mile
Redstone
Youghiogheny
SOMERSET
BEDFORD
Monongahela
FAYETTE
Casselman
Wills
GREENE
George
Fish
Dunkard
Cheat

ON CERTAIN GENERALIZATIONS OF THE PROBLEM OF THREE BODIES.

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(Read April 23, 1909.)

The object of the following note is fourfold: first, to determine all the problems of three bodies in which the bodies describe conic sections, under central conservative forces, whatever be the initial conditions of the motion; second, to specialize the preceding solutions, so as to single out those in which the force-function contains only the masses of the bodies and their mutual distances; third, to generalize the latter group to the case in which the orbits are the most arbitrary possible; fourth to generalize the last to the case in which the functions defining the orbits appear in the potential function.

1. If three given particles $(r_1, \theta_1; m_1)$, $(r_2, \theta_2; m_2)$, $(r_3, \theta_3; m_3)$ describe, under central censervative forces, three given coplanar curves whose equations in polar coördinates referred to the center of gravity of the system are

$$(1) \qquad f_1(r_1, \theta_1)=0, \quad f_2(r_2, \theta_2)=0, \quad f_3(r_3, \theta_3)=0,$$

the forces are derived from a potential function which may be written in the form[1]

$$(2) \qquad P=\frac{c^2}{2}\frac{\sum_{i=1}^{3} m_i\left\{\left(\frac{\partial f_i}{\partial r_i}\right)^2+\left(\frac{1}{r_i}\frac{\partial f_i}{\partial \theta_i}\right)^2\right\}}{\left\{\sum_{i=1}^{3} m_i r_i\frac{\partial f_i}{\partial r_i}\right\}^2},$$

[1] On employing the usual substitutions the form given follows immediately from Oppenheim's solution in rectangular coördinates. See his memoir in the third volume of the Publications of the von Kuffner Observatory.

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where c is the constant in the integral of areas, that is,

$$(3)\qquad c=\sum_{i=1}^{3} m_i r_i^2 \frac{d\theta_i}{dt}.$$

In case the orbits are described independently of the initial conditions, Oppenheim has remarked that it must be possible to throw the function P into the form

$$(4)\qquad P=P_1+h,$$

where h is a constant independent of the parameters which enter P_1; if such a decomposition of P is impossible, the motion takes place only for special values of the initial constants.

When the orbits are conic sections the equations (1) become

$$(5)\qquad f_i(r_i,\theta_i)=r^2_i(A_i\cos^2\theta_i+2H_i\sin\theta_i\cos\theta_i \\ +B_i\sin^2\theta_i)+2r_i(G_i\cos\theta_i+F_i\sin\theta_i)-C_i=0,\quad (i=1,2,3.)$$

If the corresponding functions

$$\frac{\partial f_i}{\partial r_i},\quad r_i\frac{\partial f_i}{\partial r_i},\quad \frac{1}{r_i}\frac{\partial f_i}{\partial \theta_i}$$

are constructed, and substituted in the form (2) the latter becomes

$$(6)\qquad Q=\frac{c^2}{2}\,\frac{\displaystyle\sum_{i=1}^{3} m_i\{(H_i^2-A_iB_i)r_i^2+2[(H_iF_i-B_iG_i)\cos\theta_i +(H_iG_i-A_iF_i)\sin\theta_i+F_i^2+G_i^2+(A_i+B_i)C_i\}}{\left\{\displaystyle\sum_{i=1}^{3} m_i[(G_i\cos\theta_i+F_i\sin\theta_i)r_i-C_i]\right\}^2};$$

this is the most general form of potential function giving rise to conic section trajectories in the problem of three bodies under central conservative forces.

2. From the relations

$$(7)\qquad m_i m_j \rho_{ij}^2=m_i(m_i+m_j)r_i^2+m_j(m_i+m_j)r_j^2-m_k^2r_k^2, \\ ijk=123,231,312,$$

where ρ_{ij} is the distance between the bodies $(r_i,\ \theta_i;\ m_i)$ and $(r_j,\ \theta_j;\ m_j)$, it follows that if Q is to be a function of the masses and mutual distances alone we must have

$$(8)\qquad F_i=G_i=0,\qquad (i=1,2,3).$$

If in addition we have

$$H_1^2 - A_1B_1 = H_2^2 - A_2B_2 = H_3^2 - A_3B_3 = \text{some constant,} \tag{9}$$
$$\text{say } \frac{k}{c^2}\left\{\sum_{i=1}^{3} m_iC_i\right\}^2,$$

the function Q may be written

$$Q = k\sum_{i=1}^{3} m_i r_i^2 + c^2 \frac{\sum_{i=1}^{3} m_i(A_i + B_i)C_i}{\left\{\sum_{i=1}^{3} m_iC_i\right\}^2} = Q_1 + h. \tag{10}$$

Finally, no noting that the equations (7) lead to the relation

$$\left(\sum_{i=1}^{3} m_i\right)\sum_{i=1}^{3} m_i r_i^2 = m_1m_2\rho_{12}^2 + m_2m_3\rho_{23}^2 + m_3m_1\rho_{31}^2, \tag{11}$$

we have Q_1 in the well-known form

$$Q_1 = \frac{k}{\sum_{i=1}^{3} m_i}(m_1m_2\rho_{12}^2 + m_2m_3\rho_{23}^2 + m_3m_1\rho_{31}^2), \tag{12}$$

which is thus made to appear as the unique case of conic section orbits for all initial conditions under forces varying as the masses and a function of the mutual distances.

It may be observed here parenthetically that if a similar study be made for the cubic a first condition will be found to demand that the orbits be defined by equations of the form

$$a_ix_i^3 + 3b_ix_i^2y_i - 3a_ix_iy_i^2 - b_iy_i^3 - C_i = 0, \quad (i = 1, 2, 3); \tag{13}$$

the remaining analysis of the problem offers no difficulty.

3. Writing

$$\frac{\partial f_i}{\partial r_i} = u_i, \quad \frac{\partial f_i}{\partial \theta_i} = v_i, \tag{14}$$

the function (2) becomes

$$\frac{c^2}{2}\sum_{i=1}^{3} m_i\left(u_i^2 + \frac{v_i^2}{r_i^2}\right)\Big/\left\{\sum_{i=1}^{3} m_i r_i u_i\right\}^2; \tag{15}$$

considering the case in which

$$(16) \qquad \frac{\sum_{i=1}^{3} m_i\left(u_i^2+\frac{v_i^2}{r_i^2}\right)}{\left\{\sum_{i=1}^{3} m_i r_i u_i\right\}^2} = \frac{\sum_{i=1}^{3} m_i\phi_i(r_i)}{\left\{\sum_{i=1}^{3} m_i\psi_i(r_i)\right\}^2},$$

we find immediately that

$$(17) \qquad u_i = \frac{\phi_i}{r_i}, \quad v_i^2 = r_i^2\phi_i - \psi_i^2;$$

and on subjecting these values of u_i and v_i to the condition of integrability we have the following relations

$$(18) \qquad r_i^2\phi_i - \psi_i^2 = \text{some constant, say } \lambda_i^2, \quad (i = 1, 2, 3),$$

connecting the functions ϕ_i and ψ_i. The construction of the functions defined by the equations (17) and (18) is effected directly by a simple integration which yields the result that under forces derived from the potential function

$$(19) \qquad R = \frac{c^2}{2}\sum_{i=1}^{3} m_i\left(\frac{\psi_i^2+\lambda_i^2}{r_i^2}\right) \Big/ \left\{\sum_{i=1}^{3} m_i\psi_i\right\}^2,$$

three arbitrary masses m_i describe the respective orbits

$$(20) \qquad \int \frac{\psi_i(r_i)}{r_i}\,dr_i = \pm\lambda_i\theta_i + \mu_i, \qquad (i = 1, 2, 3)$$

where the function ψ_i is absolutely arbitrary, and the quantities λ_i, μ_i are any two constants.

In virtue of the relations (7) the function R contains only the masses and mutual distances of the bodies, further, on writing the function ψ_i^2 in the form

$$(21) \qquad \psi_i^2 = a_i r_i^2 + \omega_i(r_i),$$

where ω_i is an arbitrary function and a_i any constant, it is evident that R can be written in the form (4); whence it follows that the three bodies under forces derived from (19) describe orbits of the form (20) whatever be the initial conditions of the motion of the system.

4. In order to generalize certain of the preceding results further, let us write the equations of the orbits thus

$$z_i \equiv f_i(x_i, y_i) - c_i = 0, \qquad (i = 1, 2, 3) \tag{22}$$

and the potential function as follows:

$$P = \frac{c^2}{2} \sum_{i=1}^{3} m_i(p_i^2 + q_i^2) \Big/ \left[\sum_{i=1}^{3} m_i(x_i p_i + y_i q_i) \right]^2, \tag{23}$$

the axes being rectangular about the center of gravity of the system as origin.

Let us consider now the case in which we have

$$\begin{cases} p_i^2 + q_i^2 = \phi_i(x_i, y_i, z_i; r_i), \\ x_i p_i + y_i q_i = \psi_i(x_i, y_i, z_i; r_i); \end{cases} \quad r_i^2 = x_i^2 + y_i^2 \quad (i = 1, 2, 3), \tag{24}$$

from these it at once follows that

$$\begin{cases} r_i^2 p_i = x_i \psi_i \pm y_i \sqrt{r_i^2 \phi_i - \psi_i^2}, \\ r_i^2 q_i = y_i \psi_i \mp x_i \sqrt{r_i^2 \phi_i - \psi_i^2}. \end{cases} \qquad (i = 1, 2, 3) \tag{25}$$

The condition of integrability applied to (25) gives

$$\begin{aligned} r_i^2\{2\phi_i(1 - \psi_{i_{z_i}}) + x_i\phi_{i_{x_i}} + y_i\phi_{i_{y_i}} + r_i\phi_{i_{r_i}} + \psi_i\phi_{i_{z_i}}\} - 2\psi_i(x_i\psi_{i_{x_i}} \\ + y_i\psi_{i_{y_i}} + r_i\psi_{i_{r_i}}) \pm 2(x_i\psi_{i_{y_i}} - y_i\psi_{i_{x_i}})\sqrt{r_i^2\phi_i - \psi_i^2} = 0, \\ (i = 1, 2, 3) \end{aligned} \tag{26}$$

an equation whose integration determines ϕ_i when ψ_i is given, and conversely.

(a) In case the functions ϕ_i and ψ_i contain only r_i the equation (26) becomes

$$\frac{d}{dr_i}(r_i^2\phi_i - \psi_i^2) = 0, \tag{27}$$

that is to say, it takes the form (18). Accordingly the equations (25) assume the simpler forms

$$r_i^2 p_i = x_i \psi_i \pm \lambda_i y_i, \quad r_i^2 q_i = y_i \psi_i \mp \lambda_i x_i, \tag{28}$$

whence, by integration, the orbits (20) reappear.

(b) Let ϕ_i be a function only of r_i and ψ_i a function of $n_i z_i$,

where n_i is an arbitrary constant; then the condition (26) becomes

$$(29)\qquad r_i\left\{2n_ir_i\phi_i - \frac{d}{dr_i}(r_i^2\phi_i)\right\} = 0, \qquad (i = 1, 2, 3),$$

from which we conclude that

$$(30)\qquad \phi_i = a_i^2 r_i^{2(n_i-1)},$$

a_i being any constant. The expressions (25) in this case assume the form

$$(31)\qquad \begin{cases} r_i^2 p_i = n_i x_i z_i \pm y_i\sqrt{a_i^2 r_i^{2(n_i-1)} - n_i^2 z_i^2}, \\ r_i^2 q_i = n_i y_i z_i \mp x_i\sqrt{a_i^2 r_i^{2(n_i-1)} - n_i^2 z_i^2}. \end{cases}$$

The determination of the form of z_i from the equations (31) can be affected perhaps most simply in the following manner: That ψ_i is a function only of $n_i z_i$ amounts to saying that

$$(32)\qquad z_i = x_i^{n_i} f_i\left(\frac{y_i}{x_i}\right);$$

substituting the partial derivatives of this function in one or the other of the expressions (31) we obtain the following equation:

$$(33)\qquad \pm\sqrt{a_i^2 r_i^{2(n_i-1)} - n_i^2 z_i^2} = n_i\frac{y_i}{x_i}f_i - \left(1 + \frac{y_i^2}{x_i^2}\right)f_i',$$

whence we have the ordinary differential equation

$$(34)\qquad f_i' = \frac{1}{\xi_i^2 + 1}\{n_i\xi_i f_i \pm \sqrt{a_i^2(\xi_i^2 + 1)^{n_i} - n_i^2 f_i^2}\}, \qquad \xi_i = \frac{y_i}{x_i}.$$

The integration of the latter equation may be facilitated by the substitution

$$(35)\qquad 2v_i = n_i \log(\xi_i^2 + 1),$$

under which (34) takes the form

$$(36)\qquad \frac{df_i}{dv_i} = f_i \pm \frac{1}{n_i\sqrt{e^{\frac{2v_i}{n_i}} - 1}}\sqrt{a_i^2 e^{2v_i} - n_i^2 f_i^2}.$$

Putting now

$$(37)\qquad n_i f_i / a_i e^{v_i} = \sin u_i,$$

the equation (36) becomes

$$\frac{du_i}{dv_i} = \pm \frac{1}{\sqrt{e^{\frac{2v_i}{n_i}} - 1}}; \tag{38}$$

whence

$$u_i = n_i \tan^{-1} \{e^{\frac{2v_i}{n_i}} - 1\}^{\frac{1}{2}} + \beta_i; \tag{39}$$

that is

$$f_i = \frac{\alpha_i}{n_i}(\xi_i^2 + 1)^{\frac{n_i}{2}} \sin(n_i \tan^{-1}\xi_i + \beta_i); \tag{40}$$

or finally the equations of the orbits become

$$r_i^{n_i} \sin(n_i\theta_i + \beta_i) = \gamma_i; \tag{41}$$

the corresponding form of the force-function may be written down without difficulty.

If we note that for three equal masses the relations (7) squared give

$$\rho_{ij}^4 = 4(r_i^4 + r_j^4) + r_k^4, \quad ijk = 123, 231, 312, \tag{42}$$

we see that the solution (41) for $n = 3$ is also a solution of the problem of three equal masses under forces varying as the masses and the cube of the distance.

(c) Let ϕ_i contain both z_i and r_i, while ψ_i is a function only of $n_i z_i$; the condition (26) becomes

$$2(1 - n_i)\phi_i + n_i z_i \phi_{i_{z_i}} + r_i \phi_{i_{r_i}} = 0; \quad (i = 1, 2, 3); \tag{43}$$

whence it appears that ϕ_i must have one of the forms

$$z_i^{\frac{2(n_i-1)}{n_i}} \Phi_i\left(\frac{r_i^{n_i}}{z_i}\right), \quad r_i^{2(n_i-1)} \Psi_i\left(\frac{z_i}{r_i^{n_i}}\right); \tag{44}$$

in case n_i is unity an arbitrary additive constant may be appended to each of these forms. Since Φ_i and Ψ_i are arbitrary functions we have here an infinitude of problems. Considering the second of the forms (32) a little further, the equations (25) become in this case

$$\begin{aligned} r_i^2 p_i &= n_i x_i z_i \pm y_i \sqrt{r_i^{2n_i}\Psi_i\left(\frac{z_i}{r_i^{n_i}}\right) - n_i^2 z_i^2}, \\ r_i^2 q_i &= n_i y_i z_i \mp x \sqrt{r_i^{2n_i}\Psi_i\left(\frac{z_i}{r_i^{n_i}}\right) - n_i^2 z_i^2}; \end{aligned} \tag{45}$$

and if in particular the symbol Ψ indicates the square we have

$$(46)\qquad \begin{aligned} r_i^2 p_i &= z_i(n_i x_i \pm y_i\sqrt{1-n_i^2}),\\ r_i^2 q_i &= z_i(n_i y_i \mp x_i\sqrt{1-n_i^2});\end{aligned}$$

from which we conclude that the orbits are represented by the equations

$$(47)\qquad r_i^{n_i} e^{\pm\theta_i\sqrt{1-n_i^2}+\beta_i} = \gamma_i, \qquad (i = 1, 2, 3).$$

(*d*) The case in which each of the functions ϕ_i and ψ_i contains both variables r_i and z_i leads to a multitude of problems in which these functions are subject to the single conditions

$$(48)\qquad r_i[2\phi_i(1-\psi_{i_{z_i}}) + r_i\phi_{i_{r_i}} + \psi_i\phi_{i_{z_i}}] - 2\psi_i\psi_{i_{r_i}} = 0.$$

(*e*) If

$$(49)\qquad \begin{cases} \phi_i = a_i^2 \Big/ \left\{ x_i^{2(\nu_i+n_i)}\left(1+\dfrac{y_i^2}{x_i^2}\right)^{n_i}\omega_i\left(\dfrac{y_i}{x_i}\right)\right\}, \\ \psi_i = (1-\nu_i-n_i)z_i, \end{cases}$$

where a_i an arbitrary constant, ω_i an arbitrary function, the integration follows a course parallel to that pursued under (*b*) above, and leads to complicated transcendental equations for the determination of the corresponding orbits.

VIENNA,
February 25, 1909.

THE PAST HISTORY OF THE EARTH AS INFERRED FROM THE MODE OF FORMATION OF THE SOLAR SYSTEM.

By T. J. J. SEE.

(*Read April 23, 1909.*)

In No. 4308 of the *Astronomische Nachrichten* (February, 1909) it is proved that the mode of formation of the solar system has been very different from that heretofore imagined by astronomers. It will, therefore, be of decided interest to physicists and geologists, as well as to astronomers and mathematicians, to consider the bearing of this new work upon the past history of the earth. If we could certainly recognize the general process by which the solar system was formed, it would of course follow that the earth, as one of the inner planets of that system, originated in the same way, and much new light might be thrown upon the problems of the physics of the globe.

The investigation outlined in the *Astronomische Nachrichten*, No. 4308, was undertaken for astronomical purposes only, and was therefore in no way biased by other considerations. And since the new method is accurate and conclusive, so as to demonstrate with all rigor the actual processes involved in the formation of our system, it becomes peculiarly valuable in throwing light upon the past history of the earth. In fact this new theory gives the only accurate and reliable data that we have on the subject, and it is difficult to see where other data of equal trustworthiness could be obtained. We shall therefore first summarize the process by which the solar system was formed, as shown by the researches in astronomy, and then apply this general theory to the past history of our particular planet.

Though Laplace was the greatest master of celestial mechanics since Newton, and formulated the nebular hypothesis as the culmination of his researches on the dynamics of our system, yet it was

TABLE SHOWING THE APPLICATION OF BABINET'S CRITERION TO THE PLANETS AND SATELLITES WHEN THE SUN AND PLANETS ARE EXPANDED TO FILL THE ORBITS OF THE BODIES REVOLVING ABOUT THEM.

Solar System.

Planet.	R_0 The Sun's Observed Time of Rotation.	P_0 Observed Period of Planet.	R_1 Time of Sun's Rotation Calculated by Babinet's Criterion.
Mercury	25.3 days = 0.069267 yrs.	0.24085 yrs.	479 yrs.
Venus		0.61237 "	1673 "
The earth		1.00000 "	3192 "
Mars		1.88085 "	7424 "
Ceres		4.60345 "	24487 "
Jupiter		11.86 "	86560 "
Saturn		29.46 "	290962 "
Uranus		84.02 "	1176765 "
Neptune		164.78 "	2888533 "

Sub-systems.

Planet.	Satellite.	R_0 Adopted Rotation of Planet.	P_0 Observed Period of Satellite.	R_1 Time of Planet's Rotation Calculated by Babinet's Criterion.
The earth	The moon	1 day	27.32166 days	3632.45 days
Mars	Phobos	$24^h.62297$	7.6542 hours	190.62 hours
	Deimos		30.2983 "	1193.52 "
Jupiter	V	$9^h.928$	11.9563 "	64.456 hours
	I		1.7698605 days	14.60 days
	II		3.5540942 "	35.900 "
	III		7.1663872 "	93.933 "
	IV		16.7535524 "	290.63 "
	VI		250.618 "	10768.8 "
	VII		265.0 "	11602.4 "
	VIII		930.73 "	61997.1 "
Saturn	Inner edge of ring	$10^h.641$	0.236 "	0.6228 days
	Outer edge of ring		0.6456 "	2.383 "
	Mimas		0.94242 "	4.2902 "
	Enceladus		1.37022 "	7.0615 "
	Tethys		1.887796 "	10.822 "
	Dione		2.736913 "	17.751 "
	Rhea		4.517500 "	34.620 "
	Titan		15.945417 "	186.05 "
	Hyperion		21.277396 "	273.06 "
	Iapetus		79.329375 "	1580.1 "
	Phœbe		546.5	20712 "
Uranus	Ariel	$10^h.1112$ (Cf. A. N., 3992)	2.520383 "	33.714 "
	Umbriel		4.144181 "	65.435 "
	Titania		8.705897 "	176.05 "
	Oberon		13.463269 "	314.83 "
Neptune	Satellite	$12^h.84817$ (Cf. A. N., 3992)	5.87690 "	141.8 "

reserved for Babinet of Paris to point out[1] a rigorous mechanical law which enables the mathematician to test the nebular hypothesis. Nevertheless, Laplace himself constantly uses the same principle, in the law of the conservation of areas, though he does not apply it to the development of our system. The principle involved is that of the constancy of the moment of momentum of axial rotation. According to this law, we have

$$C = \sum mr^2\omega = \omega\sum mr^2 = \omega'\sum mr'^2, \tag{1}$$

where r is the radius of the rotating globe, ω the angular velocity of rotation, and C a constant; while r' and ω' are the corresponding quantities at some other epoch. Thus at any two epochs, however much the freely rotating globe may have changed by contraction or expansion, we always have

$$\omega' r'^2 = \omega r^2. \tag{2}$$

By taking accurate values of the radii and rotation-periods of the sun and planets as now observed, we may calculate the corresponding rotation-periods when the globes are imagined expanded to fill the orbits of the planets and satellites. The accompanying table gives the most important data for the solar system.[2]

It will be found from this table that the sun would have rotated with extreme slowness if it had been expanded to the orbits of the several planets, and the planets also would have rotated very slowly if they had been expanded to fill the orbits of their satellites. The difference between the observed periods of revolution and the calculated periods of rotation is so great that we readily see that the planets could never have been detached from the sun, and the satellites could never have been detached from the planets, by acceleration of rotation as imagined by Laplace. It is evident, therefore, that all of these bodies have been captured or added from without, and have had their orbits reduced in size and rounded up under the secular action of the nebular resisting medium formerly pervading the planetary system.

Ever since the time of Laplace it has been believed that our

[1] *Comptes Rendus*, Tome 52, p. 481, March 18, 1861.

[2] Cf. *Astron. Nachr.*, no. 4308.

system was formed from a nebula, and to-day we know that this nebula was of the spiral type, due to the automatic coiling up under mutual gravitation of two or more streams of cosmical dust. Wherever such streams meet, or pass near one another, there is developed a cosmical vortex, with rotation about a center, and a definite moment of momentum about an axis. This is due to the fact that the impact is never central, but always unsymmetrical, and thus gives rise to a rotation.

The two or more streams which meet continue to wind up, under the effects of mutual gravitation, and thus we have the different observed types of spiral nebulæ. The nebula continues to rotate and the coils are drawn closer and closer together, and the whole mass slowly settles towards its center. The planets, which are formed by the agglomeration of cosmical dust in the convolutions of the nebula, revolve constantly in the surrounding nebular medium. As the planetary bodies grow by the gathering in of the cosmical dust in which they revolve their orbits are reduced in size and rounded up under the secular action of the resisting medium.

It is shown by this line of inquiry, and especially by the roundness of Neptune's orbit, that our system extends much beyond Neptune; and that the orbits now observed to have a round form were originally much larger and also much more eccentric than they are now seen to be. It is impossible to determine definitely how much the orbits have been reduced in size, but owing to the almost total obliteration of the eccentricity, it seems certain that they were originally two or three times larger than they are now.

Moreover, it is proved that in a resisting medium of given density the secular effect is proportionally greater on a small planet than on a large one. This is owing to the fact that the mass, and therefore the moment of momentum, is proportional to the cube of the planet's radius, but the surface, and therefore the resistance of the medium, proportional to the square of the radius; so that the changes in the orbit of a small body are greater than in that of a large body in the inverse ratio of the radius, for masses of the same mean density.

Accordingly it follows that small planets, such as the asteroids or inner planets were at a former epoch, when revolving in a

nebula, have a tendency to settle towards the center more rapidly than large planets. In our system the asteroids have been gathered into their present position partly by the effects of resistance, and partly by the disturbing action of Jupiter, which throws them into the stable region within his orbit. When the paths of the asteroids cross his orbit, the motion is shown to be unstable, and therefore such overlapping orbits are temporary and not permanent.

It follows, therefore, that the orbit of the earth was originally much larger and much more eccentric than at present. The earth may have begun to form almost as far away as Jupiter's orbit, or even beyond it. In time the primordial earth was thrown within that orbit, where the asteroids now revolve. Thus the earth revolved in safety and continued to grow by gathering up more and more cosmical dust. The history of Mars was similar. The major axis of the orbit was decreased by the effects of resistance, and at the same time the eccentricity steadily diminished, till we have the planets as they are to-day. This is as certain as anything can be, and it throws an interesting light on the past history of our earth. While the information thus given us is meager, it is, so far as I know, our only means of fathoming the mystery which has always surrounded the origin of our planet.

We may therefore say that in the beginning the earth was a small body like one of the asteroids; it then revolved in a much larger and more eccentric orbit than at present, and was augmented gradually by the sweeping up of cosmical dust in its ceaseless motion around the sun. In general, this process of building up the earth was excessively slow, though at times the motion through streams may have given larger additions of matter; but the full process may have occupied a billion years. Of course, geological history began only after the earth had attained about its present dimensions. And the study of the crust of the globe shows that no large additions to the matter of our planet have been made since geological history began. The sedimentary rocks are not filled with any considerable amount of meteoric matter precipitated from the heavenly spaces.

From these considerations it follows that the earth was built up very gradually by accretion; and that this growth took place because our globe was revolving in a resisting medium made up of

fine cosmical dust. In the later periods of the earth's history, the medium has been so rare that but little matter has been added to our globe; so that not only is the whole history very long, but the latter part longer than the earlier part, as measured by the accretion then going on. In other words, the accretion now taking place is so slow as to give us by calculation, based on the observed rate, an exorbitant age of the earth; while that once going on was so large as to give too short a duration for the genesis of our planet. All estimates on the age of the earth must therefore be subject to a wide margin of uncertainty. But we may feel entirely confident that we have at length recognized the true process by which the earth was formed.

There is, however, a modifying cause which should be taken into account, in our final judgment of the process involved. It cannot be assumed that the sun was of its present mass at the start; on the contrary, we must suppose this mass to have steadily increased. The result of the augmentation of the sun's mass would be a decrease in the length of the year. Thus while the resisting medium reduced the major axis and eccentricity of the planetary orbits, the growth of the sun's mass also shortened the periodic times, without, however, decreasing the mean distance of these masses to any appreciable extent.[3]

In the actual history of our system, these two causes have therefore conspired together and the results now observed must be ascribed to both causes combined. If we wish to inquire at what rate a change of a given percentage in the sun's mass would affect the length of the year, we may proceed as follows. By a well known law for circular motion we have

$$M+m=\frac{4\pi^2a^3}{t^2}. \tag{3}$$

If we differentiate this expression, considering M and t alone to be variable, we shall get

$$dM(t^2)+(M+m)2tdt=0,$$

or

$$\frac{dM}{M+m}=-\frac{2dt}{t}. \tag{4}$$

[3] Cf. Laplace, "Mécanique Celeste," Liv. X., Chap. VII., § 21.

This simple expression shows that a change of a given percentage in M produces a contrary change half as large in t. In other words, if the sun's mass be *increased by one per cent.*, the length of the year will thereby be *decreased by two per cent.* Thus in the lapse of ages the augmentation of the sun's mass may have shortened the periods of the planets very materially; and this would slightly decrease their mean distances, as in the case of the resisting medium. Nevertheless, a gradual change in the sun's mass would not affect the eccentricity as it does the major axis.

Accordingly the small size and round form of the planetary orbits must be explained mainly by the secular effects of the resisting medium formerly pervading our system. And as the earth has been formed by accretion, and not at all by detachment from the sun, as supposed by Laplace, it follows that the matter of the globe is essentially of the same character throughout. For we have elsewhere shown that friction and resistance to motion in the body of our globe would prevent the heavier elements from separating from the lighter ones. So that the old theories which ascribe an iron nucleus to the earth must be given up as unjustifiable and misleading. And the increase of density, rigidity, and temperature towards the center is due principally to the pressure of the superincumbent matter upon the layers confined within. It is this pressure which gives the globe its great effective rigidity. If the pressure were relieved, the imprisoned matter, which now behaves as solid, would expand as vapor, owing to the high temperature still existing within the globe.

U. S. Naval Observatory,
Mare Island, California,
April 5, 1909.

ADDENDUM ON THE VIEWS OF EULER, 1749.

EULER'S REMARKS ON THE SECULAR EFFECTS OF THE RESISTING MEDIUM UPON THE ORBITAL MOTION OF THE EARTH, AND ON THE ORIGIN OF THE PLANETS AT A GREAT DISTANCE FROM THE SUN.

In view of the results briefly indicated in *Astronomische Nachricten,* No. 4308, and of the paramount part played by the resisting medium in shaping the orbits of the planets and satellites, as well as the orbits of the attendant bodies in other cosmical systems observed in the immensity of space, some remarks of the celebrated Leonard Euler are of much interest to contemporary astronomers and mathematicians. These remarks are included in the *Philosophical Transactions of the Royal Society* for 1749, pp. 141–142, under the title: "Part of a Letter from Leonard Euler, Professor of Mathematics at Berlin and F.R.S., to the Rev. Mr. Caspar Wetstein, Chaplain to the Prince of Wales, dated, Berlin, June 28, 1749; read November 2, 1749." And this is followed by a similar extract from a second letter to Wetstein, dated, Berlin, December 20, 1749, read March 1, 1750.

The views of Euler here set forth are very remarkable not only for the insight they show into the mechanism of the heavenly motions, but also into the true mode of origin of our solar system. It must be remembered that, in reaching these views on cosmogony, Euler preceded both Kant (1755) and Laplace (1796), and that he was the first mathematician since Newton to consider the secular effects of a resisting medium. His views on the origin of the planets are therefore free from every possible prejudice, and the direct outcome of the continued action of forces which he believed to be operative in the heavenly spaces.

Newton seems to have held that the spaces where the planets move are essentially as devoid of matter as a vacuum. This is expressly stated in first paragraph of the General Scholium to the "Principia." Yet he may have believed that some waste matter is diffused in the celestial spaces, for in the paragraph just before the General Scholium, he says:

The vapors which arise from the sun, the fixed stars, and the tails of the comets may meet at last with, and fall into, the atmosphere of the planets by their gravity.

Cheseaux was the first to express the view that the heavenly spaces are not perfectly transparent, but that light suffers a certain amount of absorption or extinction in passing over great distances. (Cf. L. de Cheseaux, "Traité de la Cométe qui a paru en 1743 et 1744," 8°, Lusanne & Geneva, 1744, p. 223.) This account of Cheseaux was written five years before the promulgation of Euler's views, and it is uncertain to what extent, if at all, Newton and Cheseaux had influenced Euler in reaching the conclusion that the planets suffer resistance in their motion about the sun.

The extracts from Euler's letters are as follows:

1. *First Letter:*

XXII. Monsieur le Monnier writes to me that there is, at Leyden, an Arabick manuscript of Ibn Jounis (if I am not mistaken in the name, for it is not distinctly written in the letter), which contains a history of Astronomical observations. M. le Monnier says, that he insisted strongly on publishing a good translation of that book. And as such a work would contribute much to the improvement of Astronomy, I should be glad to see it published. I am very impatient to see such a work which contains observations, that are not so old as those recorded by *Ptolemy*. For having carefully examined the modern observations of the sun with those of some centuries past, although I have not gone further back than the 15th century, in which I have found *Walther's* observations made at Nüremberg; yet I have observed that the motion of the Sun (or of the Earth) is sensibly accelerated since that time; so that the years are shorter at present than formerly; the reason of which is very natural, for if the earth, in its motion, suffers some little resistance (which cannot be doubted, since the space through which the planets move, is necessarily full of some subtile matter, were it no other than that of light), the effect of this resistance will gradually bring the planets nearer and nearer the sun; and as their orbits thereby become less, their periodical times will also be diminished. Thus in time the earth ought to come within the region of Venus, and in fine into that of Mercury, where it would necessarily be burnt. Hence it is manifest that the system of the planets cannot last forever in its (present) state. It also incontestibly follows that this system must have had a beginning; for whoever denies it must grant me, that there was a time, when the earth was at the distance of Saturn and even farther, and consequently that no living creature could subsist there. Nay there must have been a time when the planets were nearer to some fixt stars than to the Sun; and in this case they could never come into the solar system. This then is a proof, purely physical, that the world in its present state, must have had a beginning, and

must have an end. In order to improve this notion, and to find with exactitude how much the years become shorter in each Century; I am in hopes that a great number of older observations will afford me the necessary succours.

2. *Second Letter:*

XXIII. I am still thoroughly convinced of the truth of what I advanced that the orbs of the planets continue to be contracted, and consequently their periodic times grow less. . . . The late Dr. Halley has also remarked that the revolutions of the moon are quicker at present than they were in the time of the ancient Chaldeans, who have left us some observations of Eclipses.

Euler then discusses the difficulty of finding the number of days since the time of Ptolemy, and thinks the uncertainty may be a day or two, also raises the question whether the length of the day is constant.

At present we measure the length of the day by the number of oscillations which a pendulum of given length makes in this space of time; but the ancients were not acquainted with these experiments, whereby we might have been informed, whether a pendulum of the same length made as many vibrations in a day as now. But even though the Ancients had actually made such experiments, we could draw no inferences from them, without supposing, that gravity on which the time of an oscillation depends, has always been of the same force; but who will ever be in a condition to prove this invariability in gravity?

He finally concludes that both the lengths of the year and day are diminishing, "so that the same number will answer nearly to a year."

The views of Euler here set forth that the earth and other planets were at one time farther from the sun than at present are so remarkable that it is scarcely necessary to do more than bring them to the attention of astronomers.

U. S. Naval Observatory,
Mare Island, California,
April 24, 1909.

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TO THE AUTHOR OF THE BEST DISCOVERY, OR MOST USEFUL INVENTION, RELATING TO NAVIGATION, ASTRONOMY, OR NATURAL PHILOSOPHY (MERE NATURAL HISTORY ONLY EXCEPTED) UNDER THE FOLLOWING CONDITIONS :

1. The candidate shall, on or before November 1, 1910, deliver free of postage or other charges, his discovery, invention or improvement, addressed to the President of the American Philosophical Society, No. 104 South Fifth Street, Philadelphia, U. S. A., and shall distinguish his performance by some motto, device, or other signature. With his discovery, invention, or improvement, he shall also send a sealed letter containing the same motto, device, or other signature, and subscribed with the real name and place of residence of the author.
2. Persons of any nation, sect or denomination whatever, shall be admitted as candidates for this premium.
3. No discovery, invention or improvement shall be entitled to this premium which hath been already published, or for which the author hath been publicly rewarded elsewhere.
4. The candidate shall communicate his discovery, invention or improvement, either in the English, French, German, or Latin language.
5. A full account of the crowned subject shall be published by the Society, as soon as may be after the adjudication, either in a separate publication, or in the next succeeding volume of their Transactions, or in both.
6. The premium shall consist of an oval plate of solid standard gold of the value of ten guineas, suitably inscribed, with the seal of the Society annexed to the medal by a ribbon.

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TO THE SECRETARIES OF THE

AMERICAN PHILOSOPHICAL SOCIETY

NO. 104 SOUTH FIFTH STREET

PHILADELPHIA, U. S. A.

PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA

FOR PROMOTING USEFUL KNOWLEDGE

VOL. XLVIII. MAY–AUGUST, 1909. No. 192.

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PHILADELPHIA

THE AMERICAN PHILOSOPHICAL SOCIETY

104 SOUTH FIFTH STREET

1909

American Philosophical Society

General Meeting—April 21-23, 1910

The General Meeting of 1910 will be held on April 21st to 23rd, beginning at 2 p. m. on Thursday, April 21st.

Members desiring to present papers, either for themselves or others, are requested to send to the Secretaries, at as early a date as practicable, and not later than March 19, 1910, the titles of these papers, so that they may be announced on the programme which will be issued immediately thereafter, and which will give in detail the arrangements for the meeting.

Papers in any department of science come within the scope of the Society, which, as its name indicates, embraces the whole field of useful knowledge.

The Publication Committee, under the rules of the Society, will arrange for the immediate publication of the papers presented.

I. MINIS HAYS
ARTHUR W. GOODSPEED
JAMES W. HOLLAND
AMOS P. BROWN

Secretaries.

Members who have not as yet sent their photographs to the Society will confer a favor by so doing; cabinet size preferred.

It is requested that all correspondence be addressed

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THE EVOLUTION OF THE CITY OF ROME FROM ITS ORIGIN TO THE GALLIC CATASTROPHE.

BY JESSE BENEDICT CARTER.

(*Read April 22, 1909.*)

In a normally constituted man time and space are in permanent coördination. In the world of historical science such a permanent coördination is sought after, but not yet everywhere obtained. The student of history and the student of topography are too apt to work in ignorance of each other. The history of Rome has usually been written with small regard for that material and physical thing, the city of Rome; while the writer on topography is far too apt to see the buildings and the piazzas of ancient Rome as an empty stage, a place for action, but for an action in which he is not professionally interested.

Yet the transition through which so many of the natural sciences have recently gone, the change from being merely descriptive to being biogenetic, ought to serve as a lesson to the topographer. It is not possible to study even the site of ancient Rome without taking into account the vicissitudes of history in which this site has been involved.

I would accordingly ask your attention today to an attempt to sketch in its outlines the development of the city of Rome from its earliest beginnings through the Gallic catastrophe. Such a bio-

graphical sketch (for under this treatment the city itself becomes endowed with life and the product is veritably a biography) covers a distinct field in that long series of periods which follow one another in the story of the Eternal City.

Yet this period of the origins has been strangely neglected by modern scholars, at least in so far as attempts at the coördination of material are concerned. The student of ethnography has formed his own opinions regarding the early settlement of this part of Italy, the student of language has drawn his own deductions; the student of religion has discovered certain perfectly definite things regarding the civilization of these primitive peoples; and the student of topography has made his own discoveries, but has also held his own counsel. Yet the language of communication between these special students has been in the main the old traditional one of Rome's founding.

The greatest difficulty which confronts the student of the origins of Rome is not the absence of statements regarding it, but rather the superabundant presence of such statements. If what was afterwards the great city of Rome had been entirely unknown in its birth, we would have placed it in the category of many other famous individuals, and thought nothing of it. But the presence of such a plenitude of sources has at least two bad results; first it leads to endless and hopeless attempts to reconcile conflicting statements[1]; and second even after our reason has convinced us that these statements are without authority and represent merely the late products of artificial legend making, we have great difficulty in casting them to one side, and we unconsciously and instinctively recur to them, so much are they a portion of our intellectual heritage. We may prove that Romulus was not known in Rome until after the Gallic catastrophe,[2] and that we have no reason to suppose the Palatine settlement to be any older that the Capitoline or the

[1] Compare the attempts periodically made to reconstruct the early history of Rome on the basis of the legendary accounts.

[2] See Carter: "The Death of Romulus," *American Journal of Archæology*, 1909, pp. 19–29; and (more fully) my forthcoming article, s. v. "Romulus," in Roscher's "Lexikon der griechischen und romischen Mythologie."

Quirinal,[3] but out of the ruins of our tradition Romulus, Remus and the wolf arise. Thus it is that we are still presenting the subject according to the scheme and phraseology of Varro, though there is scarcely any other part of Varro's learning which we accept unhesitatingly.

In the first place our study of Roman religion and its coördination with the study of the primitive religions of today have shown us that, down to the dawn of history, the inhabitants of the region of Rome were a semi-barbarous people. Their religion was still involved in animism. They felt themselves surrounded by a countless host of potentialities, whose names they knew, but of whose nature they were otherwise ignorant, except in so far as that nature externalized itself in definite acts.[4] Their religious organization shows that this primitive people was divided, as its most original division, into curiæ or brotherhoods, and that every member of the community must of necessity belong to one of these curiæ.[5] Their religion shows us further that their interests were agricultural.[6]

Further we know that they lived in little communities on the hilltops surrounded by a circular wall or stockade. Such a primitive settlement was certainly not a city—an urbs. At best it might be dignified by being called a town, an oppidum.[7]

The geological character of the campagna, the presence of vast

[3] See below, and also "Roma Quadrata and Septimontium," *American Journal of Archæology*, 1908, p. 181.

[4] See Wissowa: "Religion und Kultus der Roemer," p. 20, "Sämmtliche Gottheiten sind sozusagen rein praktisch gedacht als wirksam in all denjenigen Dingen, mit denen der Roemer im Gange des gewöhnlichen Lebens zu thun hat"; and Carter, "Religion of Numa," p. 5 ff.

[5] If we accept the theory that matriarchy existed in Rome before the institution of the patriarchal system, we are virtually driven to consider the Curiæ as preceding the family. For an excellent discussion of the Curiæ, cp. Eduard Meyer, "Geschichte des Altertums," Vol. II., p. 511 ff.

[6] Cp. the table of gods for this early period, as reconstructed by Mommsen, "Corpus Inscriptionum Latinarum," Vol. I., Part 1, ed 2, p. 288, or by Wissowa, "Religion und Kultus," p. 18 and cp. p. 20: "es spiegeln sich in ihr (der alten Götterordnung) die Interessen einer in Ackerbau und Viehzucht . . . lebenden Gemeinde."

[7] Cp. the investigations of E. Kornemann, "Polis und Urbs," in "Klio Beiträge zur alten Geschichte," 1905, p. 72 ff.

quantities of running water, and the consequent erosion, produced a large number of tongue-shaped or circular elevations, admirably suited to such settlements.[8] These clusters of houses surrounded by a ring-wall were merely habitations. The people tilled the fields in the valleys below. It is impossible for us to distinguish clearly between these hill-top towns in their early history. They were probably very similar in population and consequently in customs. Judging however by the presence or absence in historic times of old cult centers it would seem that there was no settlement upon the Aventine,[9] possibly because it was too close to the river. Nor does there seem to be any particular justification for supposing that the Palatine was in any sense the leader in this group of hill towns, by virtue either of its superior age or of its greater influence. The Palatine is singularly free from old cult associations.[10] Such associations as seem old are connected with the later legends, for example that of Romulus and Remus, which did not arise until the fourth century, and even in these cases the Capitoline offers a distinct rivalry to the Palatine.[11] It is easy to understand how at a later day the Palatine might have been elevated into this position of superiority.[12]

[8] Cp. the presentation of Richter: "Topographie der Stadt Rom," p. 25, 26.

[9] At least in later times it is known as pagus Aventinensis, CIL., XIV., 2105 (inscription from Lanuvium); and the fact that it was later opened to the plebeians for settlement would indicate the absence of any older settlement. The town of Aventum is an unfortunate suggestion of Jordan ("Topographie," I., 1, 182) and never had existence. Cp. Huelsen in Pauly-Wissowa's "Encyclopædie der classischen Altertumswissenschaft," s. v Aventinus, Sp. 2283, 23 ff.

[10] Cacus and the very doubtful Caca, in whom Wissowa ("R. und K.," p. 24, note 1) is inclined to see a pair of ancient gods, belong really on the Aventine rather than on the Palatine. Huelsen's statement (Jordan-Huelsen, I. 3, p. 45), "von den Kulten auf dem Palatin cheinen einige in sehr alte Zeit hinauf zu gehen, wie der der Febris, der Fortuna, der Dea Viriplaca, der Luna Noctiluca," must be taken merely relatively, as none of the deities mentioned (with the exception of the uncertain Dea Viriplaca) precede the later kingdom.

[11] Cp. the rival casa Romuli on the Capitoline; and the Salii Palatini versus the Salii Collini.

[12] Owing to its popularity as a residence during the closing years of the Republic, and the preference of Augustus and his successors.

This little group of towns is not as yet however the city of Rome: it is possible that in the course of time it might have become the city of Rome, either by the superior power of one oppidum which would shortly have added the others to its territory, in somewhat the way in which the traditional account considers that Rome was actually founded,—the Varronian scheme, which proceeds from the presupposition of the primacy of the Palatine,—or by some sort of reciprocity, resulting in union, of which we see the first traces in the annual joint sacrifices of the Septimontium.[13] But either one of these ways would have required a very long period of time, and in either case the intellectual development of the people would have been continuous so that the traces of barbarism even in the conservative field of religion would have been much fewer in number. Every indication points to a rapid change and one which affected the towns equally. Such a change could come only from outside, and from a people superior to Rome in culture. When we ask what this people was, the answer comes more clearly every year,—the Etruscans.

It seems fairly certain that the Etruscans as we know them in the history of Italy were a composite people made up of a native Italic stock combined with an invading stock, whose original home was in Asia Minor.[14] Further it seems probable that the invading stock came by sea across the Mediterranean and landed on the western coast of Italy, and that their advent did not precede the beginning of the eighth century.[15] Allowing them about two centuries

[13] On the Septimontium, compare Varro, L. L. 6, 24: dies Septimontium nominatus ab his septem montibus, in quis sita urbs est, feriæ non populi sed montanorum modo, ut paganalia qui sunt alicuius pagi; and the interesting treatment by Wissowa in the Satura Viadrina-Gesammelte Abhandlungen, p. 230 ff. Cp. also Platner: "Classical Philology," I., 1906, p. 69.

[14] The hypothesis of the East, more especially of Asia Minor, as the original home of the Etruscans is at present pretty generally adopted. Their acquaintance with the Babylonian haruspicina and with Greek mythology, the general plan of their houses and the shape of their helmets all indicate an eastern origin. For details see the admirable résumé of the present condition of the Etruscan problem by Körte in Pauly-Wissowa s. v. Etrusker.

[15] Whether the Etruscans came by land or by sea is still a subject of discussion, though the hypothesis of the sea route seems to be gaining strength at the expense of the other. There seem to be traces of their movement on

to accomplish their amalgamation and conquer the region afterwards known as Etruria, they would come into contact with the Roman stock in the plain of Latium about the beginning of the sixth century.[16]

The Etruscans, therefore, a sea-faring and so a city-loving folk, conquered these hill towns and enclosed them all together with the intervening valleys with one wall. But before building this wall, they drew the plough about the space to be enclosed and thus created the pomerium *ritu Etrusco*.[17] We do not know very much about their wall but we do know about the pomerium, and as the wall was surely inside of it,[18] we have a general idea of its position.

the islands of the eastern Mediterranean, especially on Lemnos, where an inscription practically Etruscan in character has been found. It is uncertain exactly what we are to call these people before the "Etruscan" people were brought into being by the amalgamation of this immigrant stock with the Italic stock. It has been suggested with a reasonable degree of probability that they were the Pelasgians. The date at which they entered Italy is a matter of some considerable uncertainty. The date as given above (circa 800) depends upon the validity of the supposition that in the long series of tombs which the cemeteries (especially near Bologna) show, the earlier tombs are not of the Etruscans but only the later ones, the tombe-a-corridoio, and the tombe-a-camera. However several scholars, who are in hearty accord with the eastern origin, and the journey by sea, are not content with so late a date as the eighth century, on the ground that it does not allow sufficient time for the development of the Etruscans in the peninsula of Italy. According to them the coming of the Etruscans should be placed two or three centuries earlier.

[16] This date corresponds with the tradition of the later kingdom. Tarquinius Priscus reigned thirty-eight years, Servius Tullius forty-four years, Tarquinius Superbus twenty-five years, a total of one hundred and seven years, which added to B. C. 509, the supposed year of the founding of the Republic, gives B. C. 616, as the beginning of the so-called Later Kingdom. Such an agreement may be of absolutely no value, on the other hand it may have a certain significance if the tradition represents the faint reflection of the period of time when the new influence came.

[17] Not only the Pomerium, but the whole idea of delimitation seems to have come to Rome from Etruria. Much of the terminology of Roman surveying bears the imprint of Etruria. Roman tradition recognized the Etruscan origin of the Pomerium: cp. Varro, L. L. V., 143: oppida condebant in Latio Etrusco ritu multi, id est iunctis bobus, tauro et vacca, interiore aratro circumagebant sulcum.

[18] On the whole question of the pomerium and its relation to the city wall, compare *American Journal of Archæology,* 1908, p. 177.

Thus was created what the topographers call "the city of the four regions."[19] It would be preferable to use the old Roman term *urbs et capitolium,* for this city, the *urbs* did indeed contain four regions, but apart from the city though inclosed in the same wall was the citadel, the *capitolium.*[20] Such an arrangement is in itself an added proof that the Palatine was not the ruling spirit. The Etruscans coming from without were free from prejudice and chose the Capitoline as their citadel simply because it offered superior advantages from the fortificatory standpoint.

On the Capitoline arose the Etruscan temple of Jupiter, Juno and Minerva. It is strange that the Etruscan character of this cult has not been more readily recognized. Minerva herself is more than half an Etruscan deity, hitherto unknown to Rome,[21] and the triad, Jupiter-Juno-Minerva, is a favorite among the Etruscans. The temple was built in the Etruscan style by Etruscan workmen and the ornamentation and the very images of the gods came from Etruria.[22]

With the coming of the Etruscans begins a tradition which has in part an historical value. This tradition presents us with the figure of Servius Tullius, unquestionably a real person, probably the

[19] "Die Vierregionenstadt" of the Germans. I do not know of any instances of the term in antiquity. The ancient term seems to have been urbs et capitolium.

[20] The capitolium had of course a protecting wall of its own. This is clear from the fact that it was capable of being held against the Gauls, even after the Gauls had captured the city proper. The other hill-top oppida which were included in the urbs certainly had walls of their own, but these walls probably ceased to be kept up after the large surrounding wall was built. In the case of the Capitolium however the original wall was preserved and probably strengthened.

[21] Minerva has no festival in the old calendar, the so-called calendar of Numa. The Quinquatrus which occurs in that calendar and which is ordinarily associated with Minerva had originally no connection with her, but belonged entirely to Mars. Minerva's cult seems to have originated at Falerii and to have spread from there into Etruria and also into Rome. On Minerva, cp. Wissowa in Roscher's Lexikon, s. v. Minerva, and "Religion und Kultus," p. 203; and Carter, "Religion of Numa," p. 44 ff.

[22] The image of Jupiter came from Etruria; compare Pliny (N. H., XXXV., 157) and Ovid (F., I., 201 ff.); also the quadriga on the roof (Pliny, *l. c.*). The workmen employed on the temple gave the name to the Vicus Tuscus, where they lived.

first historical character in the annals of Rome. But though the character of Servius is a real one, legend has added many of the "events" attributed to him. One of these events concerns our own theme—it is the building of the wall of Rome. The tourist knows this wall as the inner of the two walls, of which traces still remain in Rome, that wall of which there are remnants beside the railway station and on the Via Nazionale.[23] Up to the present the statement that Servius built a wall has been accepted as an historical fact, and though it was recognized that the so-called Servian wall as we know it dates from the end of the fourth century before Christ, scholars have almost always assumed that there was another wall on the same spot and that this previous wall dated from the Servian age.[24] But, as I hope to be able to show in a moment, this is an altogether gratuitous assumption, and serves simply to hinder the understanding of history. In the first place there is absolutely no proof that Servius Tullius built a wall, other than the name "Servian wall" which attaches to a structure obviously of the fourth century. The tradition would in any case be worthless, but we have not even a consistent tradition. A study of the growth of the city as attributed to the various kings brings no profit, but exhibits merely a mass of contradictions and inconsistencies.[25] So far as the name

[23] Sections of this wall are constantly being discovered. At the date of writing (April, 1909) a very fine piece has been unearthed near the Spithoever property.

[24] The only exception to this statement known to me is Eduard Meyer (Hermes, XXX., 1895, p. 13): "dass die Servianische Mauer nicht älter ist als das vierte Jahrhundert, ist seit O. Richter's Nachweis unumstösslich. Sie umschliesst die Grossstadt der Samniterkriege." That this statement has not been more appreciated is doubtless owing to the fact that it is capable of being understood to apply merely to the date of the actually existing Servian wall, leaving always the possibility that it implies another wall on the same site preceding the "Servian" wall.

[25] In Dionysius of Halicarnassus (4, 13) and in Strabo (p. 234M) Servius Tullius is aid to have added the Esquiline and the Viminal; but Livy (1, 44, cp. the author of de vir. ill. 7) says that he added the Quirinal and the Viminal and increased the Esquiline; whereas the Quirinal is elsewhere (Dionys. 2, 50, Strabo, p. 234M) supposed to have been included in the city of Romulus and Titus Tatius. On the other hand the so-called Servian wall included the Aventine, hence Servius is supposed to have added this hill to the city, whereas a very strong ancient tradition attributed the

itself is concerned, in the minds of the contemporaries and successors of Cato a wall at that time nearly two hundred years old would be easily associated with the kingdom and might readily be named after the most famous of the kings, Servius Tullius. There are in other words no traces of a real Servian wall either preserved in monumental form for the topographer or found in the historical records. The occasional references found in Livy to the gates of what we know as the "Servian Wall," in connection with events which happened at or before the Gallic catastrophe, are most rightly explained as anachronisms, and they offer no difficulty to one who is accustomed to the vagaries of the Roman historians.[26]

On the contrary, it is on the face of it extremely unlikely that an enlargement of the city limits would have been necessary so soon after the building of the large encircling wall which we attribute to the Etruscans. Yet, as a matter of fact, the so-called "Servian Wall" includes a much larger space than the wall of the "Four-Region City."[27] It includes on the northeast the high tableland where the Quirinal and the Viminal unite, but still more important it includes the Aventine. It is the inclusion of the Aventine which creates the chief difficulties in understanding the history of Rome until after the Gallic catastrophe. Let us try the experiment of considering the Aventine as a suburb and of reading our history under such a condition.[28] The city which the Etruscans founded and in which Servius Tullius lived, and according to our present assumption the only city of Rome until after the Gallic

addition to Ancus Martius (Cicero de rep. 2, 18; Dionys. Hal. 3, 43; Strabo, p. 234M; Liv. 1, 33; de vir. ill. 5). The difference of opinion regarding the Caelian is still more marked. On the whole question compare Jordan, "Topographie," II., p. 206, 207.

[26] *E. g.*, Livy (5, 41) speaks of the Gauls as entering by the Porta Collina, referring doubtless to the gate in the "Servian" wall, as it existed in his day.

[27] At this point the reader may be inclined to challenge these statements and to ask what we know of the course of the wall of the Four Region City. Of the wall itself we know nothing, but we do know that it lay inside the pomerium, and we know approximately the course of the pomerium, and to what extent it in its turn lay inside the Servian wall.

[28] It may require a certain amount of practice to conduct this experiment successfully, just as it takes practice to eliminate the arch of Severus in reconstructing the Forum of the Republic and early empire.

catastrophe, was that particular form of the city which the topographers call "the city of four regions" and which was more familiarly known in history as *urbs et capitolium.*

In the first place we note the permanency of the phrase *urbs et capitolium*[29] and we ask whether it is likely that the phrase would have obtained such immortality if the form of the city to which it was applicable had so soon given way to the other form, the so-called Servian city. The permanence of the name seems to argue for the long existence of that particular city from which the name was derived. In the second place the annals of religion offer us in this early period at least this knowledge, namely, the establishment of temples to various deities more or less strangers to Rome, in the region outside of the pomerium.[30] One of the most important of these deities was Diana. She came into the religious life of the state merely because of her connection with the Latin league, and her temple was not a temple of Rome alone but of the whole league.[31] This temple was situated on the Aventine,[32] and while of course it was outside the pomerium it has always been difficult to understand why Rome made bold to put a league temple inside her city wall, when all the expanse of the Campus Martius was at her disposal. But if as we are now supposing the Aventine also was a suburb, the difficulty disappears. Conversely when the temple of Apollo[33] was built, while it must of necessity have been outside the pomerium, it is difficult to see why it should have been placed in the exposed Campius Martius, when there was the possibility of placing it on the Aventine itself outside the pomerium but sup-

[29] Urbs et capitolium occurs; Cæsar de bell. civ. 1, 6, 7; Liv. 3, 18, 0; cp. Liv. 38, 51, 13; Flor. Epit. 2, 6, 45; Jord. Rom. 202.

[30] A useful list of these temples and their dates is given in Wissowa's "Religion und Kultus," p. 516 ff. It is based largely on E. Aust, de ædibus sacris populi Romani unde a primis liberæ reipublicæ temporibus usque ad Augusti imperatoris ætatem Romæ conditis. Marburg, 1889.

[31] Cp. Carter, "Religion of Numa," p. 53 ff.; Wissowa, "Religion und Kultus," p. 198 ff. and in P. W. sub verbo. Diana came into the worship of the league as the goddess of Aricia.

[32] For the question of the exact location of this temple, cp. Jordan-Huelsen, "Topographie," I. 3, p. 158 ff. It is found on fragment 3 of the Forma Urbis Romæ.

[33] On the temple of Apollo, cp. Jordan-Huelsen, "Topographie," p. 535 ff.

posedly protected by the city wall. For the worship of Apollo was purely an affair of the Roman state, and hence could well be inside the wall provided it was outside the pomerium. But again under our present supposition we realize that the Aventine also was a suburb and hence, so far as protection was concerned, it would be a matter of indifference whether the temple was on the Aventine or in the Campus Martius.

Turning from the field of religion to that of constitutional development, it has always been difficult to understand why there should have been only four city tribes, named after the four regions, in case the city so soon extended its borders and took in the Aventine. But if the Aventine was added two centuries later it will readily be seen that the force of habit two centuries old caused the number of city tribes to be limited to four even when the city had exceeded the local limits of the four old regions.

But when we turn to the question of the increase in Rome's population and the disposal of it we have our best argument for treating the Aventine as a suburb. The population was increasing rapidly—we see signs of it in the growing number of foreigners both tradespeople and handicraftsmen. By degrees there arose a problem very similar to that of modern Rome, a dearth of houses for the working classes. It was then (456) that a law was passed providing for the plebeians on the Aventine.[34] Had the Aventine been an internal part of the city it is difficult to see why it would not have been occupied long before. But as an extreme measure the expedient of giving the plebeians land in the suburbs might easily have been adopted.

Thus it was that the city began to outgrow its walls, both in the Aventine region and in the Campus Martius. The proof of this outgrowing is given us in the story of the Gallic catastrophe in B. C. 390. For it is only thus that we can understand why the city was no longer capable of defending itself, and why the Gauls captured it without difficulty, the capitolium alone offering a successful resistance. The tradition of the Gallic catastrophe seems to do

[34] On this law, the lex Icilia, cp. Dionys. 10, 31, and Liv. 3, 31, 1.

violence to the truth in at least two respects; first in underestimating the completeness of the Gallic victory; and second with that sublime indifference to contradiction which is so apt to characterize tradition, by overestimating the amount of physical damage which the Gauls did to the city. At a later time it was customary to attribute all the crookedness and lack of plan which characterized the arrangement of the city streets and buildings to the haste with which Rome was rebuilt after it had been destroyed by the Gauls.[35] But this presupposes that the Gauls wrought an amount of destruction which would partake of an industry quite at variance to what we know of their natural indolence. But quite aside from the question of destruction the Gallic catastrophe had brought one lesson home to the Romans, namely, that their city needed a defence. It is not surprising that in the years following the retreat of the Gauls a new wall was built on a new line so as to include the now populated Aventine. To include the suburb at the south of the Campus Martius was impossible because of engineering difficulties.

It is no wonder therefore that a passage in the sixth book of Livy (chapter 32) dealing with the year B. C. 378 speaks of the building of a wall,[36] and that another passage (Book VII., Chapter 20, under the year B. C. 353) speaks of repairs to walls and towers.[37] Rome was beginning her conquest of Italy, and it was necessary that she should herself be protected from hostile forces. This is accordingly the epoch from which dates the so-called Servian Wall.

[35] Cp. the striking passage in Livy (5, 55): antiquata deinde lege promisce urbs ædificari cœpta. Tegula publice præbita est, saxi materiæque cædendæ, unde quisque vellet, ius factum prædibus acceptis eo anno ædificia perfecturos. Festinatio curam exemit vicos dirigendi, dum omisso sui alienique discrimine in vacuo ædificant. Ea est causa, ut veteres cloacæ, primo per publicum ductæ, nunc privata passim subeant tecta, formaque urbis sit occupatæ magis quam divisæ similis. Cp. also the passage in Tacitus (Annal., 15, 38) where he compares the rebuilding of Rome after the Gallic catastrophe with the rebuilding after Nero's fire.

[36] Et tantum abesse spes veteris levandi fenoris, ut tributo novum fenus contraheretur in murum a censoribus locatum saxo quadrato faciundum.

[37] Legionibusque Romam reductis reliquum anni muris turribusque reficiendis consumptum, et ædis Apollinis dedicata est.

With the capture of the city by the Gauls, Rome enters upon her period of inviolability for almost exactly eight hundred years, and the thought suggests itself irresistibly that the reputation for inviolability thus gained may have been a large factor in preserving her inviolate. Even in these early days the city began to be "that so holy spot, the very Rome."

ROME, April 2, 1909.

THE LINEAR RESISTANCE BETWEEN PARALLEL CONDUCTING CYLINDERS IN A MEDIUM OF UNIFORM CONDUCTIVITY.

By A. E. KENNELLY.

(*Read April 24 1909.*)

It is the purpose of this paper to present formulas and tables for the computation of the linear resistances, conductances and capacities between parallel cylindrical conductors, or between a cylindrical conductor and a parallel indefinitely extending conducting plane. As is shown in the appended bibliography, the problem is by no means new; but the mathematical mode of presentation, and the arithmetical tabulation, here offered, are believed to be new. It is hoped that these will be useful to students of electrical engineering. Antihyperbolic functions are the natural vehicles of expression adapted to this problem.

Infinite Conducting Plane and Parallel Cylinder.

Linear Resistance.—Let a uniform conducting cylinder of radius

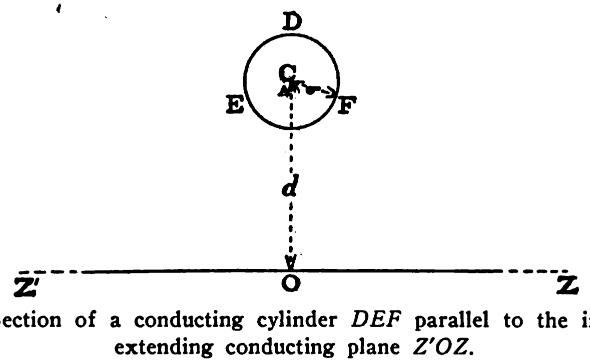

Fig. 1. Section of a conducting cylinder *DEF* parallel to the indefinitely extending conducting plane *Z′OZ*.

σ cm., shown in section at *DEF* in Fig. 1, be situated at an axial distance d cm. from a parallel indefinitely extending conducting

plane $Z'OZ$. Let the space above the plane unoccupied by the cylinder be filled by an indefinitely extending medium of uniform resistivity ρ absohm-cm. Then the linear resistance between the plane and the cylinder, *i. e.*, the resistance of the medium between them, as comprised between a pair of infinite parallel planes perpendicular to the cylinder and 1 cm. apart, will be

$$r_p = \frac{\rho}{2\pi} \cosh^{-1}\left(\frac{d}{\sigma}\right) \quad \text{absohm-cms. or C.G.S. magnetic units of resistance in a linear cm.} \qquad (1)$$

If the conducting surface EDF of the cylinder were unrolled into a flat conducting ribbon $2\pi\sigma$ cm. in breadth, and the ribbon were supported parallel to the plane $Z'OZ$ at a uniform distance $L = \sigma \cosh^{-1}(d/\sigma)$ cm. above it, as indicated in Fig. 2, with vertical insulating side walls, Ez' and Fz, to limit the flow of current through the medium to the parallel distribution shown; then the rectangular slab of medium $EFzz'$ of Fig. 2, would be the equivalent in electric resistance to the indefinitely extending plane and cylinder system of Fig. 1.

In Fig. 2 the depth, or distance across the slab, following the lines of current flow, is $L = \sigma \cosh^{-1}(d/\sigma)$ cm., and the

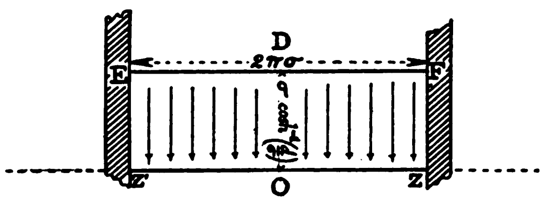

FIG. 2. Equivalent slab section corresponding to infinite plane and parallel cylinder of Fig. 1.

surface area of each face of the slab, per linear cm. of its length, is $S = 2\pi\sigma$ cm.²/cm. so that the linear resistance of the whole is

$$r_p = \frac{L}{S}\rho = \rho\frac{\sigma \cosh^{-1}(d/\sigma)}{2\pi\sigma} = \frac{\rho}{2\pi}\cosh^{-1}\left(\frac{d}{\sigma}\right) \quad \text{absohm-cm.} \qquad (2)$$

Since the linear resistance of the plane cylinder system of Fig. 1, or of the slab in Fig. 2, does not depend upon its absolute dimensions, the scale of linear dimensions in the diagram may be chosen

such that $\sigma = 1$ unit, in which case the depth of the slab is $\cosh^{-1} d$ units and the breadth of the slab is 2π units.

The quantity Y defined by the relation

$$Y = \cosh^{-1}(d/\sigma) \qquad \text{numeric (3)}$$

may be called the *distance factor* of the plane-cylinder system; because the distance between electrodes in the equivalent slab of Fig. 2 is

$$L = Y\sigma \qquad \text{cm.}$$

When the radius σ of the cylinder is very small with respect to the distance d; so that d/σ is a large number, we have

$$Y = \log_e \frac{2d}{\sigma} \qquad \text{numeric (4)}$$

so that for such cylinders the linear resistance

$$r_p = \frac{\rho}{2\pi} Y = \frac{\rho}{2\pi} \log_e \frac{2d}{\sigma} \qquad \text{absohm-cm. (5)}$$

The accompanying table gives for successive values of d/σ in column I., the corresponding value of Y in column II. Column III. gives the resistance factor $Y/2\pi$ which, when multiplied by the resistivity ρ of the medium, gives the linear resistance of the plane-cylinder system considered.

Thus, if a conducting cylinder with a radius of 2 cm. is supported at an axial distance of 10 cm. from an infinite conducting plane, in a medium of resistivity $\rho = 3 \times 10^{10}$ absohm-cms., we have $d/\sigma = 5$. The table gives for this ratio the value of Y as 2.2924, and the value of the resistance factor $Y/2\pi = 0.3649$; so that the linear resistance of the system will be $3 \times 10^{10} \times 0.3649 = 1.0947 \times 10^{10}$ absohm-cms.; or 10.947 ohms in a linear cm.

Linear Conductance.—The linear conductance, or conductance per linear cm. of the plane-cylinder system will be by (1)

$$g_p = \frac{2\pi}{\rho \cosh^{-1}(d/\sigma)} = \frac{2\pi}{\rho Y} = \gamma \cdot \frac{2\pi}{Y} \qquad \text{abmhos per cm. (6)}$$

where γ is the uniform conductivity of the medium in abmhos per

cm. The quantity $2\pi/Y$ may be called the *conductance-factor* of the plane-cylinder system. It appears in column V. of the table.

Thus, if a conducting cylinder of radius $\sigma = 0.5$ cm. be supported at an axial distance of $d = 7.5$ cm. from an infinite conducting plane, in a medium of conductivity $\gamma = 10^{-10}$ abmhos per cm., the ratio d/σ in column I. is 15, and the conductance factor for this ratio appears in column V. as 1.848. The linear conductance of the system is thus 1.848×10^{-10} abmhos per cm. The distance-factor of the system is given in column II. as 3.4001; so that the depth of the equivalent rectangular slab of medium is 1.700 cm., the breadth being 3.142 cm.

Linear Electrostatic Capacity.—The linear capacity c_p of a plane-cylinder system in a dielectric medium of specific inductive capacity κ, is numerically the same as the linear conductance of the same system in a medium of conductivity $\kappa/4\pi$ or resistivity $4\pi/\kappa$; so that, in C.G.S. electrostatic units:

$$c_p = \frac{\kappa}{2\cosh^{-1}(d/\sigma)} = \kappa \cdot \frac{1}{2Y} \quad \text{statfarads per cm.} \quad (7)$$

The values of the capacity factor $1/(2Y)$ appear in column VI. of the table for each selected value of d/σ.

Thus, a cylinder of radius $\sigma = 0.4$ cm. is supported at an axial distance of 1 cm. from an infinite conducting plane in a medium of $\kappa = 1$. Here $d/\sigma = 2.5$, and $1/(2Y) = 0.3192$. The linear capacity of the system is therefore 0.3192 statfarad per cm.

In order to convert the linear capacity c_p statfarads per cm. into microfarads per km., expressed by c_p', we have:

$$c_p' = \frac{c_p}{9} = \frac{\kappa}{9} \cdot \frac{1}{2Y} \quad \text{microfarads per km.} \quad (8)$$

Similarly, to express the linear capacity in microfarads per mile

$$c_p'' = \frac{c_p}{5.591} = \frac{\kappa}{5.591} \times \frac{1}{2Y} \quad \text{microfarads per mile} \quad (9)$$

That is, we must divide the capacity-factor of the table by 9 to obtain microfarads per km. or by 5.591 to obtain microfarads per mile.

Potential Distribution.

On the Median Line Beneath the Cylinder.—It is well known that the flow of electric current, and the distribution of potential, between the conducting cylinder and the plane, are such as might be produced by removing the conducting cylinder and substituting a conducting polar line at A, parallel to the plane. The point A lies on the line OC, and at a distance a from the plane defined by the relation

$$a = \sigma \sinh Y = \sqrt{d^2 - \sigma^2}. \qquad \text{cm. (10)}$$

The values of the polar ratio a/σ are given in the table in column VII. for each of the selected ratios d/σ up to $d/\sigma = 50$, beyond which the difference between a/σ and d/σ is less than 1 part in 5,000. For most practical purposes, it is, therefore, sufficient to regard the polar line as coinciding with the cylinder axis when the distance of that axis from the plane exceeds 50 radii.

In the steady state of flow, the potential at any point y_1 on the line OA (Fig. 3) distant y_1 cm. from O, will be

$$u_1 = I\frac{\rho}{\pi}\tanh^{-1}\left(\frac{y_1}{a}\right) \qquad \text{abvolts (11)}$$

where I is the current strength per linear cm. of the system in absamperes, the potential of the plane $Z'OZ$ being taken as numerically zero.

Similarly, the potential at any other point y_2 on the median line OY, below A, distant y_2 cm. from O, will be:

$$u_2 = I\frac{\rho}{\pi}\tanh^{-1}\left(\frac{y_2}{a}\right) \qquad \text{abvolts (12)}$$

Consequently, if the potential of the surface of the cylinder be u_1, and y_1 be the distance of the lowest point of the cylinder from the plane, the potential of any other point on the line OA between the cylinder and the plane, distant y_2 cm. from the latter, will be:

$$u_2 = u_1\frac{\tanh^{-1}(y_2/a)}{\tanh^{-1}(y_1/a)} \qquad \text{abvolts (13)}$$

Potentials on the Median Line Above the Cylinder.—In the steady state of flow, the potential at any point y_3 on the median line OY, and distant y_3 cm. from O, above the polar point A, is:

$$u_3 = I\frac{\rho}{\pi}\coth^{-1}\left(\frac{y_3}{a}\right) \qquad \text{abvolts (14)}$$

where I and π have the same meanings as above, and the potential of the plane $Z'OZ$ is reckoned as zero.

Similarly, the potential at any other point y_4 on the median line OY, distant y_4 cm. from O, and above the polar point A, is:

$$u_4 = \frac{I\rho}{\pi}\coth^{-}\left(\frac{y_4}{a}\right) \qquad \text{abvolts (15)}$$

Consequently, if the potential of the surface of the cylinder be u_3, and y_3 be the distance of the highest point of the cylinder from the plane, the potential at any other point on the median line, above the cylinder, and distant y_4 cm. from the plane, will be:

$$u_4 = u_3\frac{\coth^{-1}(y_4/a)}{\coth^{-1}(y_3/a)} \qquad \text{abvolts (16)}$$

Potentials at Points Outside the Cylinder and off the Median Line.—If the point in the plane $Z'YZ$ at which the potential is required, lies off the median line OY, the potential may be expressed either:

(a) In terms of rectangular coördinates z and y of the point.

(b) In terms of the ratio of radii vectores to the point, from the polar point A, and from its image.

(a) *Potential in Terms of Rectangular Coördinates.*—Let P, Fig. 3, be the point whose potential is required, and whose rectangular coördinates are y and z, measured respectively along the median line OY, and the line OZ in the infinite conducting plane. Then u, the potential of P, is:

$$u = \frac{I\rho}{2\pi}\tanh^{-1}\left(\frac{2ay}{a^2+y^2+z^2}\right) \qquad \text{abvolts (17)}$$

where I, ρ and a have the values previously assigned, and the potential of the plane $Z'OZ$ is reckoned as zero. Eliminating $I\rho/\pi$ with the aid of (11), we have:

$$u = u_1\frac{\tanh^{-1}\left(\frac{2ay}{a^2+y^2+z^2}\right)}{2\tanh^{-1}(y_1/a)} \qquad \text{abvolts (18)}$$

u_1 is the potential of the conducting cylinder, upon the lowest point of which $y = y_1$ and $z = 0$. Thus, taking the point P in Fig. 3, defined by the coördinates $y = 1$ and $z = 2$, and referring the

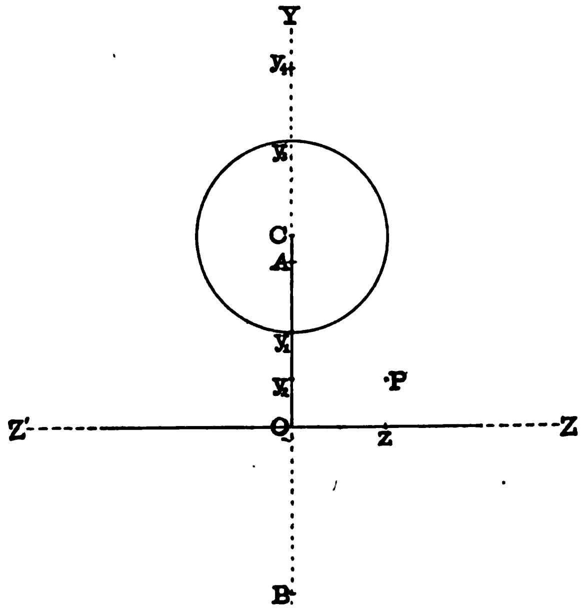

FIG. 3. Coördinates of a point at which the potential is required.

potential u of P to u_1, the potential of the surface of the cylinder, where $y_1 = 2$, $z = 0$, we have $a = 3.4642$ and

$$u = u_1 \frac{\tanh^{-1}(6.9284/17)}{2 \tanh^{-1}(2/3.4642)} = 0.3285 u_1.$$

Formula (18) may also be presented in the form:

$$u = u_1 \frac{\tanh^{-1}\left(\frac{2ay}{a^2 + y^2 + z^2}\right)}{\tanh^{-1}\left(\frac{2ay_1}{a^2 + y_1^2}\right)} \quad \text{abvolts} \quad (19)$$

(*b*) *Potential in Terms of Radii Vectores.*—A line parallel to the axis of the conducting cylinder, drawn through the point B, Fig. 3, on the median line OY and with the distance $OB = OA$, may

be called the *image* of the polar line through OA. The point B, thus defined, may be called the *image polar point*. The points A and B, taken together, may be called the *polar points* of the diagram with respect to the infinite plane and cylinder.

Let P be any point in the plane of the diagram (Fig. 3). Then let r' and r be the lengths of a pair of radii vectores BP, AP, drawn from the polar points B, A, to P respectively. Let these distances $r'r$ be called the *polar distances* of the point P. Then the ratio m of these polar distances will be:

$$m = r'/r \qquad \text{numeric (20)}$$

This ratio may be called the *polar ratio*, for purposes of reference. The polar ratio will manifestly be a number greater than unity for all points in the diagram above the infinite conducting plane $Z'OZ$. It is a well known result that

$$u = \frac{I\rho}{2\pi} \log_e m \qquad \text{abvolts (21)}$$

If a point be selected on the surface of the cylinder, having a potential u_1 abvolts, and for convenience the lowest point of coördinates y_1 and $z = 0$, the polar distances of this point may be denoted by r_1' and r_1; while their ratio may be denoted by $m_1 = r_1'/r_1$. Consequently

$$u_1 = \frac{I\rho}{2\pi} \log_e m_1 \qquad \text{abvolts (22)}$$

and eliminating I, ρ and 2π between (21) (22), we have

$$u = u_1 \frac{\log_e m}{\log_e m_1} = u_1 \frac{\log_{10} m}{\log_{10} m_1} \qquad \text{abvolts (23)}$$

The potential of the infinite plane is here reckoned as zero. It may be observed that

$$m_1 = \frac{r_1'}{r_1} = \frac{a + d - \sigma}{r_1} = \frac{a + d}{\sigma} \qquad \text{numeric (24)}$$

When the cylinder radius is very small, compared with the axial distance d, $d = a$, and

$$m_1 = \frac{r_1'}{r_1} = \frac{2d}{\sigma} = \frac{D}{\sigma} \qquad \text{numeric (25)}$$

It follows from the preceding equations that the equipotential surfaces in an infinite plane-cylinder system are all cylinders having their axes situated on the median line. If u_1 be the potential of the conducting cylinder, and if we denote by Y_1 the value of the distance factor Y for this cylinder, according to formula (3), or to column II. of the table, then the distance factor Y of any cylindrical equipotential surface whose potential is u becomes

$$Y = Y_1 \frac{u}{u_1} \qquad \text{numeric (26)}$$

We have for any such cylinder the equations of condition:

$$Y = \cosh^{-1}(d/\sigma) = \sinh^{-1}(a/\sigma) = \tanh^{-1}(a/d) = \coth^{-1}(d/a)$$
$$= 2\tanh^{-1}(y/a) \qquad \text{numeric (27)}$$

whence d, the axial distance, or y coördinate, of the cylinder whose potential is u, will be along the median line OY:

$$d = \frac{a}{\tanh\left(Y_1 \frac{u}{u_1}\right)} \qquad \text{cm. (27)}$$

and the radius σ of this equipotential cylinder is:

$$\sigma = \frac{a}{\sinh\left(Y_1 \frac{u}{u_1}\right)} \qquad \text{cm. (28)}$$

The coördinate y of the lowest point of any such equipotential cylinder will be:

$$y = a\left(\frac{m-1}{m+1}\right) \qquad \text{cm. (29)}$$

$$= a\tanh\left(\frac{Y}{2}\right) = a\tanh\left(\frac{Y_1}{2}\frac{u}{u_1}\right) \qquad \text{cm. (30)}$$

so that

$$u = u_1 \frac{\tanh^{-1}\left(\frac{m-1}{m+1}\right)}{\tanh^{-1}(y_1/a)} \qquad \text{abvolts (31)}$$

an expression for the potential of a point in the medium in terms of its polar ratio m, and the distance y_1 of the conducting cylinder from the plane.

The current density δ at any point whose polar distances are r and r' will be perpendicular to the equipotential cylinder passing through the point and will be equal to

$$\delta = I \frac{\rho}{\pi} \cdot \frac{a}{rr'} \quad \text{absamperes per cm.}^2 \quad (31a)$$

The preceding formulas for potential distribution have been developed with reference to a conducting medium between the infinite plane and cylinder. They are, however, applicable to the case of a dielectric medium, if the electric flux ϕ replace the electric current I, and the dielectric constant κ be substituted for γ or $1/\rho$. No substitution will be needed in formulas (13), (16), (18), (19) and (23) to (31), inclusive, which apply either to an insulating or to a conducting medium.

Two Equal and Parallel Conducting Cylinders.

If, instead of an infinite conducting plane and a parallel conducting cylinder, as in Figs. 1 and 3, we have two indefinitely long parallel conducting cylinders of equal diameter, as in Fig. 4, at an interaxial distance CC' of D cm., then each cylinder may be regarded as forming an independent plane-cylinder system with a fictitious infinite conducting midplane $Z'OZ$, axially distant $d = D/2$ cm. from each. This midplane will be perpendicular to the central line CC'. The double-cylinder system will have two polar lines equidistant from the system center O, and represented in Fig. 4 by the polar points AA'. The potential of the midplane $Z'OZ$ will be midway between the potentials of the two cylinders; so that if these have equal and opposite potentials, the potential of the midplane will be zero. All of the preceding formulas for plane-cylinder systems may, therefore, be applied, in duplicate, to the double-cylinder system of Fig. 4.

Linear Resistance of Double Cylinder Systems.—The linear resistance from either cylinder to the midplane is given in formula

(1). Consequently, the linear resistance of the double cylinder system of Fig. 4 is

$$r_{00} = \frac{\rho}{\pi} \cosh^{-1}(d/\sigma) = \frac{\rho}{\pi} Y \qquad \text{absohm-cms.} \quad (32)$$

where $d = D/2$. The resistance factor of the system is thus Y/π, or double that given in column III. of the table.

Thus, if the two cylinders, each of radius $\sigma = 2$ cm. separated

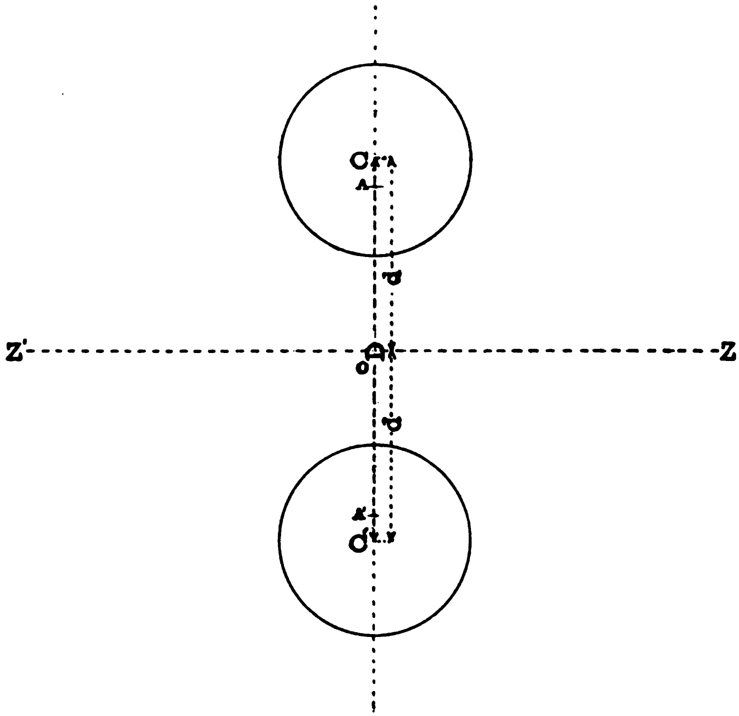

FIG. 4. Two equal and parallel conducting cylinders at interaxial distance of D cm.

by an interaxial distance $D = 8$ cm. in a medium of resistivity $\rho = 5 \times 10^{10}$ absohm-cms. we have $d = 4$, and $d/\sigma = 2$.

$Y = \cosh^{-1} 2 = 1.317$, and the linear resistance is

$$r_{00} = \frac{5 \times 10^{10}}{3.1416} \times 1.317 = 2.096 \times 10^{10} \quad \text{absohm-cms.}$$

Linear Conductance of Double-Cylinder Systems.—The linear conductance of a double cylinder system will be half that of a plane-cylinder system of equal d/σ; so that:

$$g_{00} = \frac{\pi}{\rho \cosh^{-1}(d/\sigma)} = \frac{\pi}{\rho Y} = \frac{\gamma\pi}{Y} \quad \text{abmhos per cm.} \quad (33)$$

where γ is the conductivity of the medium. The conductance-factor of the double-cylinder system is therefore half of that given in column V. of the table.

Linear Electrostatic Capacity of Double-Cylinder Systems.—The linear capacity C_{00} of a double-cylinder system in a dielectric medium of specific capacity κ is half the capacity of a plane-cylinder system of equal d/σ; so that:

$$c_{00} = \frac{\kappa}{4 \cosh^{-1}(d/\sigma)} = \kappa \cdot \frac{1}{4Y} \quad \text{statfarads per loop cm.} \quad (34)$$

The linear capacity of each cylinder to the zero-potential plane, or the capacity of the system per cylinder-cm., is given by formula (7). The capacity factors of a double-cylinder system of given d/σ are thus half of the values given in column VI. of the table; but the capacity factors of the system per "wire" cm. to zero potential midplane are those recorded in column VI.

At interaxial distances large with respect to the cylinder-radii, $Y = \log_e D/\sigma$, and we obtain the well known formula

$$c_{00} = \frac{\kappa}{4 \log_e (D/\sigma)} \quad \text{statfarads per cm.} \quad (35)$$

The linear capacity of a double-cylinder system expressed in microfarads per km. is

$$c_{00}' = \frac{c_{00}}{9} = \frac{\kappa}{9} \cdot \frac{1}{4Y} \quad \text{microfarads per cm.} \quad (36)$$

Similarly,

$$c_{00}'' = \frac{c_{00}}{5.591} = \frac{\kappa}{5.591} \times \frac{1}{4Y} \quad \text{microfarads per mile} \quad (37)$$

Potential Distribution in Double Cylinder System.—All of the formulas (10) to (31) inclusive referring to the potential distribution in a plane-cylinder system apply immediately to a double-

cylinder system, after the latter has been analyzed into two associated plane-cylinder systems.

Two Unequal Parallel Conducting Cylinders.

Let two parallel conducting cylinders, with their axes at C_1C_2, Fig. 5, have unequal radii σ_1 and σ_2 cm., and be separated by an interaxial distance D cm. If the radii were equal, the midplane $z'z$ would be the plane of zero potential, when the potentials of the cylinders are equal and opposite. The zero-potential plane is, how-

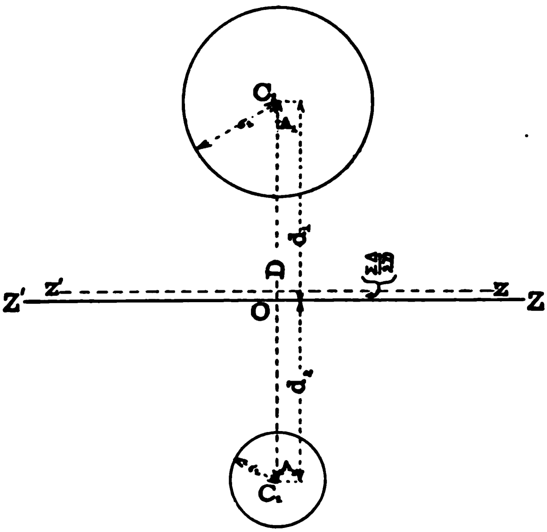

Fig. 5. Two unequal parallel conducting cylinders at interaxial distance of D cm. showing the displacement of the zero-potential plane.

ever, displaced from the larger towards the smaller cylinder through a distance of $\Sigma\Delta/2D$ cm.; so that:

$$\left.\begin{aligned} d_1 &= \frac{D}{2} + \frac{\Sigma\Delta}{2D} \qquad \text{cm.} \\ d_2 &= \frac{D}{2} - \frac{\Sigma\Delta}{2D} \qquad \text{cm.} \end{aligned}\right\} \qquad (38)$$

where $\Sigma = \sigma_1 + \sigma_2$ is the sum and $\Delta = \sigma_1 - \sigma_2$ is the difference of the cylinder radii.

After having established the position of the zero-potential plane $Z'OZ$, the linear resistance between the cylinders may be found by using formula (1) on each side of the plane and adding the two parts. The linear conductance will then be the reciprocal of this result.

The linear capacity of each cylinder to zero-potential plane is to be found by formula (7). The linear capacity per loop cm. may be found from the linear resistance per loop cm. by the formula:

$$c_{00} = \frac{\kappa}{2(Y_1 + Y_2)} \quad \text{statfarads per cm.} \quad (39)$$

For example, if two conducting cylinders of radii $\sigma_1 = 2$ and $\sigma_1 = 1$ cm., respectively, are separated in air by an interaxial distance of 8 cm., the zero-potential plane is displaced through a distance of $\frac{3}{16}$ cm., so that $d_1 = 4\frac{3}{16}$, $d_2 = 3\frac{13}{16}$ cm. The ratio d_1/σ_1 is thus 2.094, and d_2/σ_2 is 3.815. The distance factor Y_1 is 1.37, and Y_2 is 2.014. The linear capacity of C_1 is 0.365 statfarads per cm. and of C_2 0.248 statfarads per cm., each to zero-potential plane. The linear capacity of the pair by (39) is 0.1477 statfarad per loop cm.

The potential distribution in the unequal cylinder system may be obtained as easily as when the cylinders are equal, since the polar points A_1A_2, Fig. 4, lie at equal distances from the zero-potential plane $Z'OZ$.

EXCENTRIC CYLINDERS.

Let the two parallel very thin conducting cylinders be hollow, with radii σ_1 and σ_2. Let one be placed excentrically within the other, as shown in Fig. 6, at an interaxial distance D. Let the line C_1C_2 joining their centers be prolonged as indicated in the figure. The infinite zero-potential plane will perpendicularly intersect this line at an inferred distance of $\Sigma\Delta/2D$ cm. from the middle point of D; so that:

$$d_1 = \frac{\Sigma\Delta}{2D} + \frac{D}{2} \quad \text{cm.} \quad (40)$$

and

$$d_2 = \frac{\Sigma\Delta}{2D} - \frac{D}{2} \quad \text{cm.} \quad (41)$$

The linear resistance between the cylinders can now be determined by finding the linear resistance of each to the infinite conducting plane by formula (1) and then taking the difference between these linear resistances.

Thus, let $\sigma_1 = 4$ cm., $\sigma_2 = 2$ cm., $D = 1$ cm. Then $\Sigma = 6$, $\Delta = 2$, and $d_1 = 6.5$ cm., $d_2 = 5.5$ cm.

The resistance factor for d_2 by the table is 0.2657.

The resistance factor for d_1 by the table is 0.1697.

The resistance factor between d_2 and d_1 0.0960.

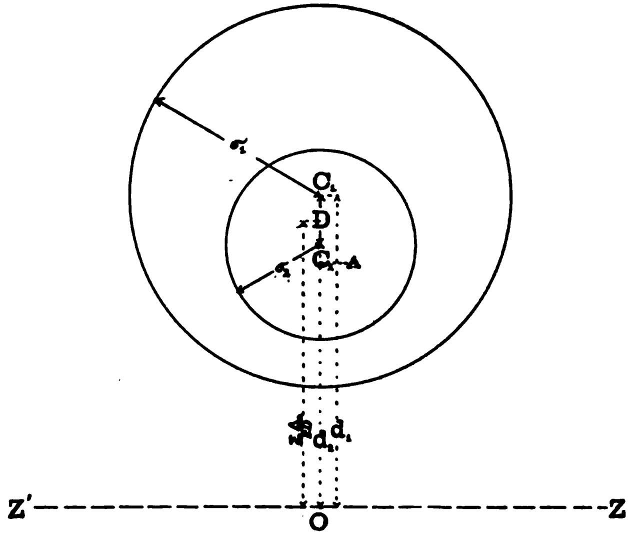

FIG. 6. Two parallel excentric cylinders, one enclosing the other, and the inferred common zero-potential plane.

which multiplied by the resistivity of the medium gives the linear resistance between the cylinders.

Through the use of formulas (40) and (41) all cases of excentric cylinders may be computed by reduction to the equivalent pair of plane-cylinder systems.

Graphical Construction of Equipotential and Stream Lines in a Plane-Cylinder System.

To draw the equipotential and stream lines of a plane-cylinder system, when the polar distance OA or distance a of the polar axis

from the parallel plane is known, draw zOK, Fig. 7, to represent the plane and on the median line OY, perpendicular to zOK mark off, to scale, the polar distance $a = OA$. Then to locate any equipotential circle of radius $\sigma = OE'$, mark off with center O, a distance $d = OC = AE'$. With center C and the required radius σ, describe the equipotential circle FEB. The distance factor Y for this circle will be expressed by

$$Y = 2 \tanh^{-1}\left(\frac{y_1}{a}\right) \qquad \text{numeric} \quad (42)$$

where y_1 is the distance OF or the y coördinate of the lowest point

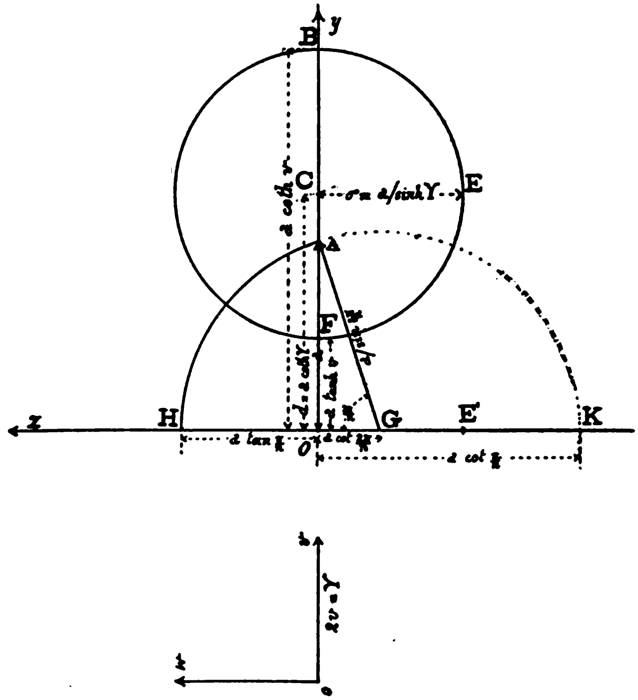

FIG. 7. Diagram for graphic construction of equipotential and stream lines.

on the circle. The potential of the circle with reference to the plane will be

$$u = \frac{I\rho}{2\pi} Y \qquad \text{abvolts (43)}$$

To draw a stream line which shall include with the median line OA the nth part of all the linear flux in the system, mark off on OK a distance $OG = a \cot 2\pi/n$; so that the angle OGA will contain $2\pi/n$ radians. Then with center G and radius GA, describe the circular arc AH, which is the required stream-line.

It may be observed that if we draw two coördinate axes ov ow in the vw plane, the function $\tanh (v + w\sqrt{-1})$ will correspond on the yz plane to the required loci, magnified by a. The locus of this function, when v is given successive constant values and w alone varies, is a series of equipotential circles, while when w is successively assigned constant values and v alone varies, the loci of successive stream-lines are produced. If w is expressed in terms of π as π/n and $2v = Y$, we have

$$OF = a \tanh v = d - \sigma \qquad \text{cm. (44)}$$

$$OB = a \coth v = d + \sigma \qquad \text{cm. (45)}$$

$$CE = a/\sinh Y = \sigma \qquad \text{cm. (46)}$$

$$OC = a \coth Y = d \qquad \text{cm. (47)}$$

also

$$OH = a \tan \pi/n \qquad \text{cm. (48)}$$

$$OK = a \cot \pi/n \qquad \text{cm. (49)}$$

$$GA = a/\sin (2\pi/n) \qquad \text{cm. (50)}$$

$$OG = a \cot 2\pi/n \qquad \text{cm. (51)}$$

Fig. 8 presents the graphical construction of the function $\tanh (v + w\sqrt{-1})$ carried from the vw plane to the yz plane, over the limits $v = -1$ to $v = +1$ and $w = -\pi/2$ to $w = +\pi/2$. The points marked on the vw plane have their corresponding points marked on the yz plane. Thus the point p defined by $v = 1.0$, $w = \pi/2$ on the vw plane is represented by the point p defined by $y = 1.313$, $z = 0$, on the yz plane, or $\tanh (1 + \pi/2 \cdot \sqrt{-1}) = 1.313$. Corresponding areas on the two planes are shaded alike. It follows from the formulas already discussed that linear resistances, conductances and capacities are the same between corresponding conducting surfaces in the two diagrams. Thus, the linear resistance of the double-cylinder system $pqrs$—$tuvx$ is equal to the linear resistance of the rectangular slab system with $pqrs$ as one electrode and $tuvx$

as the other; *i. e.*, $2/\pi$ absohm-cm. Moreover, the linear resistance of any curvilinear element, such as between qr on one cylinder, and uv on the other, in the yz system, is equal to the linear resistance between the parallel electrodes qr and uv on the rectilinear vw system ($10/\pi$ absohm-cms. with unit resistivity).

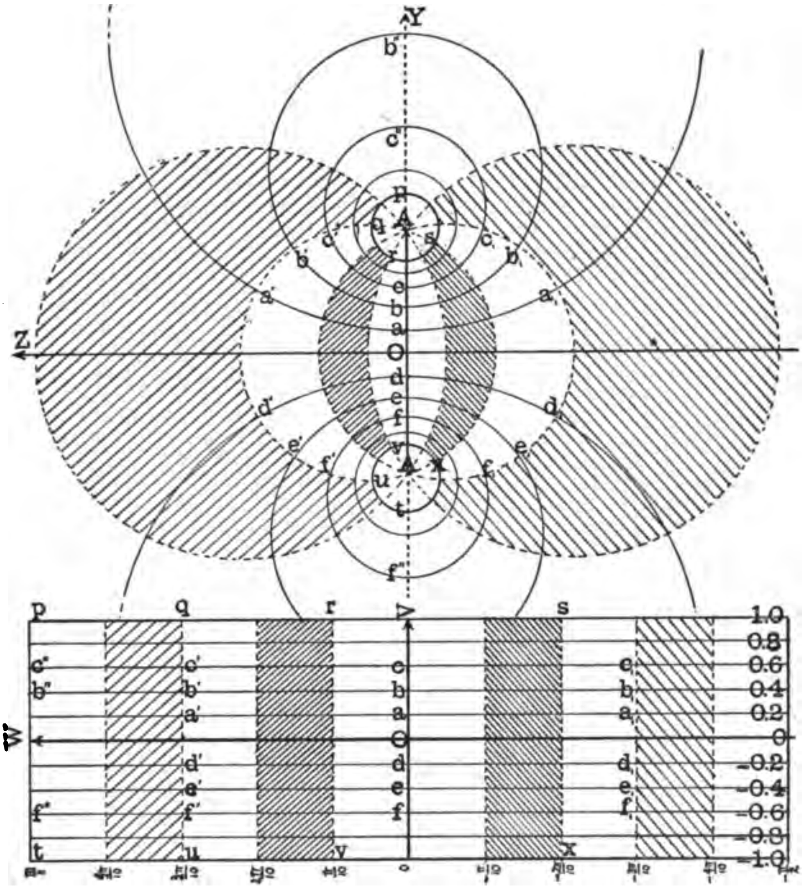

FIG. 8. Graphical comparison of $(v + w\sqrt{-1})$ and of $\tanh\,(v + w\sqrt{-1})$.

In Fig. 8, $a = OA = 1$; but it is easy to see that the proposition of equal linear resistances, conductances and capacities between corresponding conductors in the double-cylinder and corresponding rectangular slab systems, is independent of the magnification in the diagram.

I d/σ	II Distance Factor $Y = \cosh^{-1}\left(\frac{d}{\sigma}\right)$	III Resistance Factor $Y/2\pi$	IV $1/Y$	V Conductance Factor $2\pi/Y$	VI Capacity Factor $1/(2Y)$	VII $\sinh Y$ $\frac{a}{\sigma} = \sqrt{\left(\frac{d}{\sigma}\right)^2 - 1}$
1.01	0.1413	0.0225	7.0787	44.47	3.5393	0.1418
1.05	0.3149	0.0501	3.1756	19.95	1.5878	0.3202
1.1	0.4435	0.0706	2.2548	14.16	1.1274	0.4582
1.2	0.6224	0.0991	1.6067	10.095	0.8034	0.6633
1.3	0.7564	0.1204	1.3221	8.307	0.6611	0.8307
1.4	0.8670	0.1380	1.1534	7.246	0.5767	0.9798
1.5	0.9622	0.1531	1.0393	6.531	0.5197	1.1180
1.6	1.0470	0.1666	0.9551	6.002	0.4776	1.2490
1.7	1.1232	0.1788	0.8901	5.594	0.4451	1.3748
1.8	1.1929	0.1899	0.8383	5.267	0.4191	1.4967
1.9	1.2569	0.2001	0.7956	4.999	0.3978	1.6156
2.0	1.3170	0.2096	0.7593	4.771	0.3797	1.7321
2.1	1.3729	0.2185	0.7284	4.576	0.3642	1.8466
2.2	1.4255	0.2296	0.7015	4.407	0.3508	1.9596
2.3	1.4750	0.2348	0.6780	4.259	0.3390	2.0712
2.4	1.5216	0.2422	0.6572	4.129	0.3286	2.1817
2.5	1.5668	0.2494	0.6383	4.010	0.3192	2.2913
2.6	1.6096	0.2562	0.6214	3.903	0.3107	2.4000
2.7	1.6502	0.2626	0.6059	3.807	0.3030	2.5080
2.8	1.6886	0.2688	0.5922	3.721	0.2961	2.6153
2.9	1.7267	0.2748	0.5791	3.639	0.2896	2.7221
3.0	1.7627	0.2806	0.5673	3.564	0.2837	2.8284
3.1	1.7975	0.2861	0.5563	3.495	0.2782	2.9343
3.2	1.8309	0.2914	0.5462	3.432	0.2731	3.0397
3.3	1.8633	0.2966	0.5367	3.372	0.2684	3.1448
3.4	1.8946	0.3015	0.5278	3.317	0.2639	3.2496
3.5	1.9248	0.3063	0.5195	3.264	0.2598	3.3541
3.6	1.9542	0.3110	0.5117	3.215	0.2559	3.4583
3.7	1.9827	0.3156	0.5044	3.169	0.2522	3.5623
3.8	2.0104	0.3200	0.4974	3.126	0.2487	3.6661
3.9	2.0373	0.3242	0.4909	3.084	0.2454	3.7696
4.0	2.0634	0.3284	0.4846	3.045	0.2423	3.8730
4.1	2.0889	0.3325	0.4787	3.008	0.2394	3.9762
4.2	2.1137	0.3364	0.4731	2.973	0.2366	4.0792
4.3	2.1380	0.3402	0.4677	2.939	0.2339	4.1821
4.4	2.1616	0.3440	0.4626	2.907	0.2313	4.2849
4.5	2.1846	0.3477	0.4577	2.876	0.2289	4.3875
4.6	2.2072	0.3513	0.4531	2.847	0.2265	4.4900
4.7	2.2292	0.3548	0.4486	2.819	0.2243	4.5924
4.8	2.2507	0.3582	0.4443	2.792	0.2221	4.6947
4.9	2.2718	0.3616	0.4402	2.766	0.2201	4.7969
5.0	2.2924	0.3649	0.4362	2.741	0.2181	4.8990
5.1	2.3126	0.3681	0.4324	2.717	0.2162	5.0010
5.2	2.3324	0.3712	0.4287	2.694	0.2144	5.1029
5.3	2.3514	0.3743	0.4253	2.672	0.2127	5.2048

I	II Distance Factor $Y=$	III Resistance Factor	IV	V Conductance Factor	VI Capacity Factor	VII sinh Y
d/σ	$\cosh^{-1}\left(\frac{d}{\sigma}\right)$	$Y/2\pi$	$1/Y$	$2\pi/Y$	$1/(2Y)$	$\frac{s}{\sigma}=\sqrt{\left(\frac{d}{\sigma}\right)^2-1}$
5.4	2.3709	0.3773	0.4218	2.650	0.2109	5.3066
5.5	2.3895	0.3803	0.4185	2.630	0.2093	5.4083
5.6	2.4078	0.3832	0.4153	2.610	0.2077	5.5100
5.7	2.4258	0.3861	0.4122	2.590	0.2061	5.6116
5.8	2.4435	0.3889	0.4093	2.571	0.2047	5.7131
5.9	2.4608	0.3917	0.4064	2.553	0.2032	5.8146
6.0	2.4779	0.3944	0.4036	2.536	0.2018	5.9161
6.5	2.5590	0.4073	0.3908	2.455	0.1954	6.4226
7.0	2.6339	0.4192	0.3797	2.386	0.1898	6.9282
7.5	2.7036	0.4303	0.3699	2.324	0.1849	7.4330
8.0	2.7687	0.4407	0.3612	2.270	0.1806	7.9373
8.5	2.8297	0.4503	0.3539	2.224	0.1770	8.4410
9.0	2.8873	0.4596	0.3463	2.176	0.1732	8.9443
9.5	2.9417	0.4682	0.3399	2.136	0.1700	9.4472
10.0	2.9932	0.4764	0.3341	2.099	0.1670	9.9499
11	3.0890	0.4916	0.3237	2.034	0.1619	10.9545
12	3.1763	0.5055	0.3148	1.978	0.1574	11.9583
13	3.2566	0.5183	0.3071	1.930	0.1536	12.9615
14	3.3309	0.5301	0.3002	1.887	0.1501	13.964
15	3.4001	0.5411	0.2941	1.848	0.1471	14.967
16	3.4648	0.5514	0.2886	1.814	0.1443	15.969
17	3.5255	0.5611	0.2837	1.782	0.1418	16.971
18	3.5827	0.5702	0.2791	1.754	0.1396	17.972
19	3.6369	0.5788	0.2750	1.728	0.1375	18.974
20	3.6882	0.5870	0.2712	1.704	0.1356	19.975
21	3.7371	0.5948	0.2676	1.681	0.1338	20.976
22	3.7837	0.6022	0.2643	1.661	0.1321	21.977
23	3.8282	0.6093	0.2612	1.641	0.1306	22.978
24	3.8708	0.6161	0.2584	1.623	0.1292	23.979
25	3.9116	0.6226	0.2557	1.606	0.1278	24.980
26	3.9509	0.6287	0.2531	1.590	0.1266	25.981
27	3.9887	0.6348	0.2507	1.575	0.1254	26.981
28	4.0250	0.6406	0.2485	1.561	0.1243	27.982
29	4.0604	0.6462	0.2463	1.548	0.1232	28.983
30	4.0941	0.6516	0.2443	1.535	0.1221	29.983
32	4.1590	0.6619	0.2404	1.511	0.1202	31.984
34	4.2193	0.6715	0.2370	1.489	0.1185	33.985
36	4.2765	0.6806	0.2338	1.469	0.1169	35.986
38	4.3306	0.6892	0.2309	1.451	0.1155	37.987
40	4.3819	0.6972	0.2282	1.434	0.1141	39.987
42	4.4307	0.7051	0.2257	1.418	0.1129	41.988
44	4.4772	0.7126	0.2234	1.403	0.1117	43.989
46	4.5217	0.7196	0.2212	1.390	0.1106	45.989
48	4.5642	0.7264	0.2191	1.377	0.1096	47.990
50	4.6051	0.7329	0.2172	1.364	0.1086	49.990

I	II Distance Factor	III Resistance Factor	IV	V Conductance Factor	VI Capacity Factor	VII sinh Y
d/σ	$Y = \cosh^{-1}\left(\frac{d}{\sigma}\right)$	$Y/2\pi$	$1/Y$	$2\pi/Y$	$1/(2Y)$	$\frac{a}{\sigma}=\sqrt{\left(\frac{d}{\sigma}\right)^2-1}$
52	4.6443	0.7392	0.2153	1.353	0.1077	52
54	4.6821	0.7452	0.2136	1.342	0.1068	54
56	4.7184	0.7509	0.2119	1.332	0.1060	56
58	4.7535	0.7565	0.2104	1.322	0.1052	58
60	4.7874	0.7619	0.2088	1.312	0.1044	60
65	4.8676	0.7747	0.2054	1.291	0.1027	65
70	4.9416	0.7864	0.2024	1.272	0.1012	70
75	5.0106	0.7975	0.1996	1.254	0.0998	75
80	5.0751	0.8077	0.1970	1.238	0.0985	80
85	5.1358	0.8173	0.1947	1.224	0.0974	85
90	5.1930	0.8264	0.1926	1.210	0.0963	90
95	5.2470	0.8350	0.1906	1.198	0.0953	95
100	5.2983	0.8433	0.18874	1.1859	0.09437	100
110	5.3936	0.8585	0.18540	1.1648	0.09270	110
120	5.4806	0.8723	0.18246	1.1464	0.09123	120
130	5.5607	0.8852	0.17983	1.1298	0.08992	130
140	5.6348	0.8969	0.17747	1.1150	0.08874	140
150	5.7038	0.9078	0.17532	1.1016	0.08766	150
160	5.7683	0.9180	0.17336	1.0892	0.08668	160
170	5.8290	0.9278	0.17156	1.0778	0.08578	170
180	5.8861	0.9369	0.16989	1.0674	0.08495	180
190	5.9402	0.9456	0.16834	1.0577	0.08417	190
200	5.9915	0.9536	0.16690	1.0486	0.08345	200
220	6.0868	0.9688	0.16429	1.0322	0.08215	220
240	6.1738	0.9827	0.16197	1.0176	0.08099	240
260	6.2538	0.9954	0.15990	1.0047	0.07995	260
280	6.3279	1.0071	0.15803	0.9930	0.07902	280
300	6.3969	1.0180	0.15633	0.9822	0.07817	300
320	6.4615	1.0283	0.15476	0.9725	0.07738	320
340	6.5221	1.0381	0.15322	0.9634	0.07666	340
360	6.5793	1.0471	0.15199	0.9550	0.07600	360
380	6.6333	1.0557	0.15075	0.9473	0.07538	380
400	6.6846	1.0639	0.14960	0.9400	0.07480	400
420	6.7334	1.0716	0.14851	0.9332	0.07426	420
440	6.7799	1.0790	0.14749	0.9268	0.07375	440
460	6.8244	1.0862	0.14653	0.9207	0.07327	460
480	6.8669	1.0929	0.14563	0.9151	0.07282	480
500	6.9078	1.0993	0.14476	0.9096	0.07238	500
550	7.0031	1.1146	0.14279	0.8972	0.07140	550
600	7.0901	1.1284	0.14104	0.8862	0.07052	600
650	7.1701	1.1411	0.13947	0.8764	0.06974	650
700	7.2442	1.1530	0.13804	0.8674	0.06902	700
750	7.3132	1.1640	0.13674	0.8591	0.06837	750
800	7.3778	1.1741	0.13554	0.8518	0.06777	800
850	7.4384	1.1838	0.13444	0.8449	0.06722	850

I d/σ	II Distance Factor $Y = \cosh^{-1}\left(\frac{d}{\sigma}\right)$	III Resistance Factor $Y/2\pi$	IV $1/Y$	V Conductance Factor $2\pi/Y$	VI Capacity Factor $1/(2Y)$	VII sinh Y $\frac{a}{\sigma}=\sqrt{\left(\frac{d}{\sigma}\right)^2-1}$
900	7.4955	1.1930	0.13341	0.8383	0.06671	900
950	7.5496	1.2016	0.13246	0.8323	0.06623	950
1000	7.6009	1.2097	0.13156	0.8266	0.06578	1000
1100	7.6962	1.2249	0.12993	0.8165	0.06497	1100
1200	7.7832	1.2387	0.12848	0.8074	0.06424	1200
1300	7.8633	1.2515	0.12717	0.7990	0.06359	1300
1400	7.9374	1.2632	0.12599	0.7916	0.06300	1400
1500	8.0064	1.2742	0.12490	0.7848	0.06245	1500
1600	8.0709	1.2845	0.12390	0.7786	0.06195	1600
1700	8.1315	1.2940	0.12298	0.7728	0.06149	1700
1800	8.1887	1.3032	0.12212	0.7674	0.06106	1800
1900	8.2428	1.3118	0.12132	0.7624	0.06066	1900
2000	8.2941	1.3200	0.12056	0.7575	0.06028	2000
2100	8.3428	1.3278	0.11986	0.7532	0.05993	2100
2200	8.3894	1.3351	0.11920	0.7490	0.05960	2200
2300	8.4338	1.3423	0.11857	0.7451	0.05929	2300
2400	8.4764	1.3490	0.11798	0.7414	0.05899	2400
2500	8.5172	1.3555	0.11741	0.7378	0.05871	2500
2600	8.5564	1.3618	0.11687	0.7344	0.05844	2600
2700	8.5942	1.3678	0.11636	0.7312	0.05818	2700
2800	8.6305	1.3735	0.11587	0.7280	0.05794	2800
2900	8.6656	1.3791	0.11540	0.7251	0.05770	2900
3000	8.6995	1.3845	0.11495	0.7224	0.05748	3000
3100	8.7323	1.3898	0.11452	0.7196	0.05726	3100
3200	8.7641	1.3949	0.11410	0.7170	0.05705	3200
3300	8.7948	1.3996	0.11370	0.7144	0.05685	3300
3400	8.8247	1.4045	0.11332	0.7121	0.05666	3400
3500	8.8537	1.4090	0.11295	0.7098	0.05648	3500
3600	8.8818	1.4135	0.11259	0.7075	0.05630	3600
3700	8.9092	1.4180	0.11224	0.7053	0.05612	3700
3800	8.9359	1.4220	0.11191	0.7032	0.05596	3800
3900	8.9619	1.4262	0.11158	0.7012	0.05579	3900
4000	8.9872	1.4302	0.11127	0.6992	0.05564	4000
4100	9.0118	1.4342	0.11097	0.6973	0.05549	4100
4200	9.0360	1.4381	0.11067	0.6954	0.05534	4200
4300	9.0595	1.4419	0.11038	0.6936	0.05519	4300
4400	9.0825	1.4456	0.11010	0.6918	0.05505	4400
4500	9.1050	1.4491	0.10983	0.6902	0.05492	4500
4600	9.1270	1.4526	0.10957	0.6885	0.05479	4600
4700	9.1485	1.4560	0.10931	0.6869	0.05466	4700
4800	9.1695	1.4593	0.10906	0.6853	0.05453	4800
4900	9.1901	1.4627	0.10881	0.6838	0.05441	4900
5000	9.2103	1.4659	0.10857	0.6822	0.05429	5000

NOTATION.

a = polar distance or distance of polar axis from parallel plane in a plane-cylinder system, cm.
c_p = linear capacity of plane-cylinder system, statfarads/cm.
c_p' = linear capacity of plane-cylinder system, microfarads/km.
c_p'' = linear capacity of plane-cylinder system, microfarads/mile
c_{00} = linear capacity of double-cylinder system, statfarads/cm.
c_{00}' = linear capacity of double-cylinder system, microfarads/km.
c_{00}'' = linear capacity of double-cylinder system, microfarads/mile
d = distance of cylinder axis from plane, cm.
$d_1 d_2$ = distances of cylinder axes from plane in double-cylinder system with unequal cylinders, cm.
$D = 2d$ or interaxial distance between two cylinders in a double cylinder system, cm.
$\Delta = \sigma_1 - \sigma_2$ = difference in radii of two cylinders, cm.
δ = current density at a point in the medium, absamperes/cm.^{2}.
g_p = linear conductance of plane-cylinder system, abmho/cm.
g_{00} = linear conductance of double-cylinder system, abmho/cm.
κ = specific inductive capacity of medium,
γ = conductivity of medium, abmho/cm.
I = linear current in a system, absamperes/cm.
L = length of flux paths in rectangular slab, cm.
$m = r'/r$, polar ratio, or ratio of vector lengths from poles to a point in the medium, numeric
$1/n$ = a fractional part of the total linear flux, limited by a stream line.
$\pi = 3.14159 \cdots$.
r, r' = polar distances or vector lengths from poles to a point.
r_p = linear resistance of a plane-cylinder system absohm/cm.
r_{00} = linear resistance of a double-cylinder system, absohm/cm.
ϕ = linear electric flux in a system, statmaxwells/cm.
ρ = resistivity of medium, absohm-cm.
S = linear surface area of a conducting slab, cm.^{2}/cm.
$\Sigma = \sigma_1 + \sigma_2$ = sum of radii of two unequal cylinders, cm.
σ = radius of a cylinder, cm.
u = potential of a cylinder, abvolts or statvolts
vw = rectangular coördinates of points in a plane, cm.
Y = distance factor of a system $= \cosh^{-1}(d/\sigma)$, numeric
yz = rectangular coördinates of points in a plane, cm.
$y_1 y_2$ = y-coördinates of points on median line below a cylinder, cm.
$y_3 y_4$ = y-coördinates of points on median line above a cylinder, cm.

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ON AN ADJUSTMENT FOR THE PLANE GRATING SIMILAR TO ROWLAND'S METHOD FOR THE CONCAVE GRATING.[1]

By CARL BARUS.

(*Read April 24, 1909.*)

1. *Apparatus.*—The remarkable refinement which has been attained (notably by Mr. Ives and others) in the construction of celluloid replicas of the plane grating, makes it desirable to construct a simple apparatus whereby the spectrum may be shown and the measurement of wave-length made, in a way that does justice to the astonishing performance of the grating. We have, therefore, thought it not superfluous to devise the following inexpensive contrivance, in which the wave-length is strictly proportional to the shift of the carriage at the eye-piece; which for the case of a good 2-meter scale divided into centimeters, admits of a measurement of wave-length to a few Ångström units and with a millimeter scale should go much further.

Observations are throughout made on both sides of the incident rays and from the mean result most of the usual errors should be eliminated by symmetry.

In Fig. 1, *A* and *B* are two double slides, like a lathe bed, 155 cm. long and 11 cm. apart, which happened to be available for optical purposes, in the Laboratory. They were therefore used, although single slides at right angles to each other, similar to Rowland's, would have been preferable. The carriages *C* and *D*, 30 cm. long, kept at a fixed distance apart by the rod *aRb*, are in practice a length of ½-inch gas pipe, swivelled at *a* and *b*, 169.4 centimeters apart, and capable of sliding right and left and to and fro, normally to each other.

[1] The investigations in this paper were undertaken throughout in conjunction with my son, Mr. Maxwell Barus; but it seemed advisable that I should undertake the publication in these PROCEEDINGS myself, with the present acknowledgment.

The swivelling joint which functioned excellently, is made very simply of ¼-inch gas pipe T's and nipples, as shown in Fig. 2. The lower nipple *N* is screwed tight into the T, but all but tight into the carriage *D,* so that the rod *ab* turns in the screw *N,* kept oiled. Similarly the nipple *N''* is either screwed tight into the T (in one

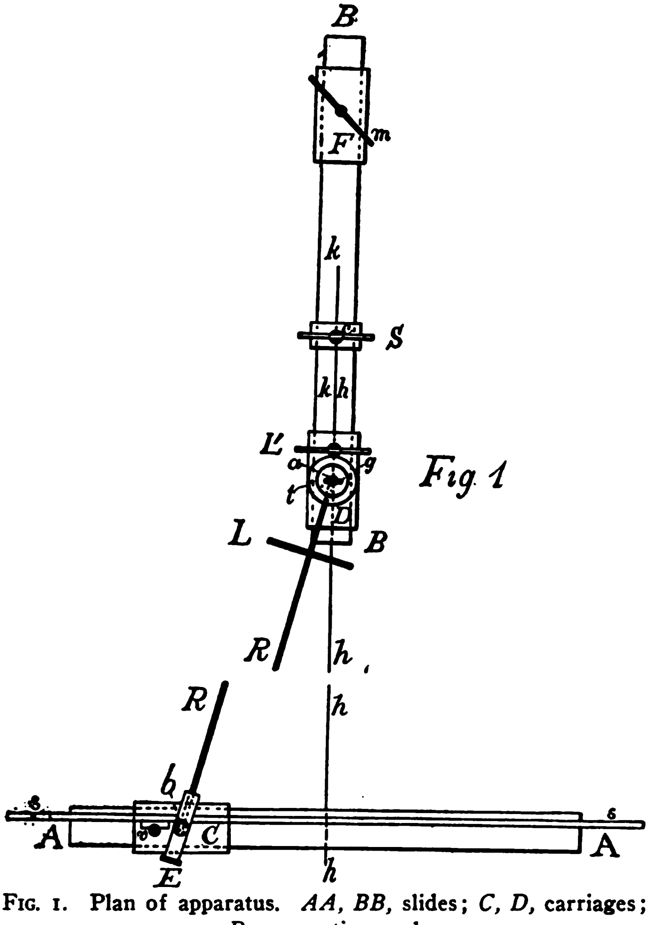


FIG. 1. Plan of apparatus. *AA, BB,* slides; *C, D,* carriages; *R,* connecting rod.

method, revoluble grating), or all but tight (in another method, stationary grating), so that the table *tt,* which carries the grating *g* may be fixed while the nipple *N''* swivels in the T. Any ordinary

laboratory clamp *K* and a similar one on the upright *c* (screwed into the carriage *S*) secures a small rod *k* for this purpose. Again a hole may be drilled through the standards at *K* and *c* and provided with set screws to fix a horizontal rod *k* or check. The rod *k* should be long enough to similarly fix the standard on the slide *S* carrying the slit and be prolonged further toward the rear to carry the flame or Geissler tube apparatus. The table *tt* is revoluble on a brass rod fitting within the gas pipe, which has been slotted across so that the conical nut *M* may hold it firmly. The axis passes through the middle of the grating, which is fastened centrally to the table *tt* with the usual tripod adjustment.

2. *Single Focusing Lens in Front of Grating.*—I shall describe three methods in succession, beginning with the first. Here a large lens *L*, of about 56 cm. focal distance and about 10 cm. in diameter, is placed just in front of the grating, properly screened and throwing an image of the slit *S* upon the cross-hairs of the eye-piece *E*, the line of sight of which is always parallel to the rod *ab*, the end *b* swivelled in the carriage *C*, as stated (see Fig. 2). An ordinary lens of 5 to 10 cm. focal distance, with an appropriate diaphragm, is adequate and in many ways preferable to stronger eye-pieces. The slit *S*, carried on its own slide and capable of being clamped to *c* when necessary, as stated, is additionally provided with a long rod *hh* lying underneath the carriage, so that the slit *S* may be put accurately in focus by the observer at *C*. *F* is a carriage for the mirror or the flame or other source of light whose spectrum is to be examined; or the source may be adjustable on the rear of the rod by which *D* and *S* are locked together.

Finally the slide *AB* is provided with a scale *ss* and the position of the carriage *C* read off by aid of the vernier *v*. A good wooden scale graduated in centimeters happened to be available, the vernier reading to within one millimeter. For more accurate work a brass scale in millimeters with an appropriate vernier should of course be used.

Eye-piece *E*, slit *S*, flame *F*, etc., may be raised and lowered by the split tube devise shown as at *M* and *M'* in Fig. 2.

3. *Adjustments.*—The first general test which places slit, grating and its spectra and the two positions of the eye-piece in one plane,

is preferably made with a narrow beam of sunlight, though lamp-light suffices in the dark. Thereafter let the slit be focused with the eye-piece on the right marking the position of the slit; next focus the slit for the eye-piece on the left; then place the slit mid-way between these positions and now focus by slowly rotating the grating. The slit will then be found in focus for both positions

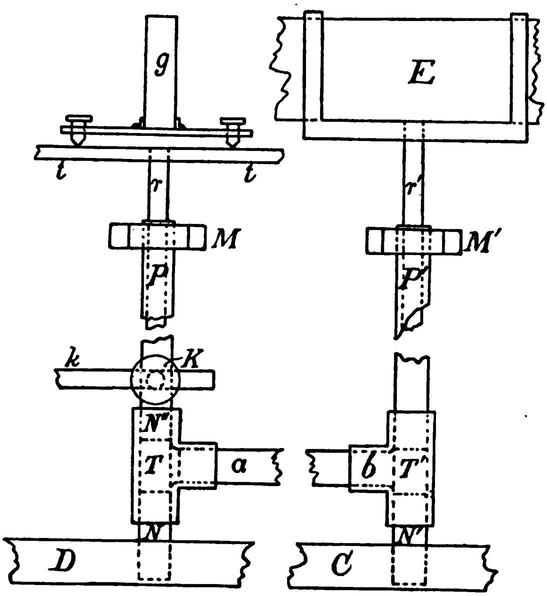


Fig. 2.

FIG. 2. Elevation of the grating (g) and the eyepiece (E) standards.

and the grating which acts as a concave lens counteracting L will be symmetrical with respect to both positions.

Let the grating be thus adjusted when fixed normally to the slide B or parallel to A. Then for the first order of the spectra the wave-length $\lambda = d \sin \theta$, where d is the grating space and θ the angle of diffraction. The angle of incidence i is zero.

Again let the grating, adjusted for symmetry, be free to rotate with the rod ab. Then θ is zero and $\lambda = d \sin i$.

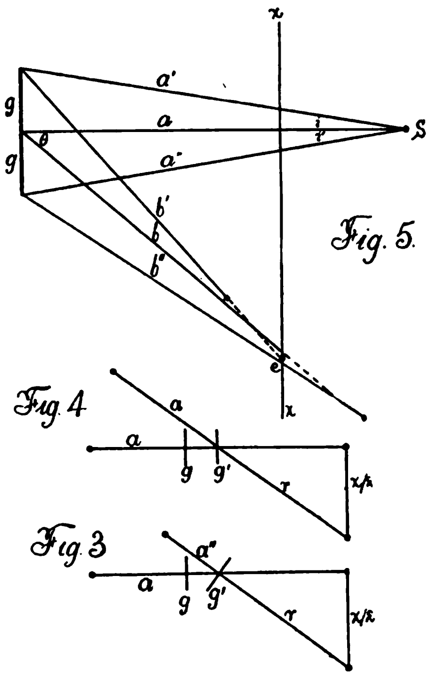
In both cases however if $2x$ be the distance apart of the car-

riage *C*, measured on the scale *ss*, for the effective length of rod $ab = r$ between axis and axis,

$$\lambda = dx/r \quad \text{or} \quad (d/2r)2x,$$

so that in either case λ and x are proportional quantities.

The whole spectrum is not however clearly in focus at one time, though the focusing by aid of the rod *hh* is not difficult. For extreme positions a pulley adjustment, operating on the ends of *h*



FIGS. 3, 4, 5. Diagrams.

is a convenience, the cords running around the slide *AA*. In fact if the slit is in focus when the eye-piece is at the center ($\theta = 0$, $i = 0$) at a distance a from the grating, then for the fixed grating, Fig. 4,

$$a' = a \frac{r^2}{r^2 - x^2},$$

where a' is the distance between grating and slit for the diffraction corresponding to x. Hence the focal distance of the grating regarded as a concave lens is $f' = ar^2/x^2$. For the fixed grating and a given color, it frequently happens that the undeviated ray and the diffracted rays of the same color are simultaneously in focus, though this does not follow from the equation.

Again for the rotating grating, Fig. 3, if a'' is the distance between slit and grating

$$a'' = a\frac{r^2 - x^2}{r^2},$$

so that its focal distance is

$$f'' = a\frac{r^2 - x^2}{x^2},$$

It follows also that $a' \times a'' = a^2$. For $a = 80$ cm. and sodium light, the adjustment showed roughly $f' = 650$ cm., $f'' = 570$, the behavior being that of weak concave lenses. The same $a = 80$ cm. and sodium light showed furthermore $a' = 91$ and $a'' = 70.3$.

Finally there is a correction needed for the lateral shift of rays, due to the fact that the grating film is enclosed between two moderately thick plates of glass (total thickness $t = .99$ cm.) of the index of refraction n. This shift thus amounts to

$$e = \frac{tx}{r}\left(\frac{1}{\sqrt{1 - x^2/r^2}} - \frac{1}{\sqrt{n^2 - x^2/r^2}}\right)\frac{b}{a}.$$

But since this shift is on the rear side of the lens L, its effect on the eye-piece beyond will be (if f is the principal focal distance and b the conjugate focal distance between lens and eye-piece, remembering that the shift must be resolved parallel to the scale ss)

$$e = \frac{tx}{r}\left(\frac{1}{\sqrt{1 - x^2/r^2}} - \frac{1}{\sqrt{n^2 - x^2/r^2}}\right)\left(\frac{b}{f} - 1\right),$$

where the correction e is to be added to $2x$, and is positive for the rotating grating and negative for the stationary grating.

Hence in the mean values of $2x$ for stationary and rotating grating the effect of e is eliminated. For a given lens at a fixed distance from the eye-piece $(b/f - 1)$ is constant.

4. *Data for Single Lens in Front of Grating.*—In conclusion we select a few results taken at random from the notes.

Grating	Line.	Observed $2x'$.	Shift.	Corrected $2x$.
Stationary	C	132.60	—.26	132.34
	D_2	118.90	—.23	118.67
	F	98.23	—.19	98.04
	Hydrogen Violet	87.87	—.16	87.71
Rotating	C	132.10	+.26	132.36
	D_2	118.45	.23	118.68
	F	97.90	.19	98.09
	H. Violet	87.50	.16	87.66

The real test is to be sought in the coresponding values of $2x$ for the stationary and rotating cases, and these are very satisfactory, remembering that a centimeter scale on wood and a vernier reading to millimeters only was used for measurement.

5. *Single Focusing Lens Behind the Grating.*—The lens L', which should be achromatic, is placed in the standard behind g. The light which passes through the grating is now convergent, whereas it was divergent in § 2. Hence the focal points at distances a', a'' lie in front of the grating; but in other respects the conditions are similar but reversed. Apart from signs, for the stationary grating

$$a' = a\frac{r^2 - x^2}{r^2},$$

and for the rotating grating

$$a'' = a\frac{r^2}{r^2 - x^2}.$$

The correction for shift loses the factor $(b/f - 1)$ and becomes

$$e = \frac{tx}{r}\left(\frac{1}{\sqrt{1 - x^2/r^2}} - \frac{1}{\sqrt{n^2 - x^2/r^2}}\right).$$

As intimated, it is negative for the rotating grating and positive for the stationary grating. It is eliminated in the mean values.

6. *Data. Single Lens Behind the Grating.*—An example of the results will suffice. Different parts of the spectrum require focusing.

Grating.	Line.	$2x'$	Shift.	$2x$
Stationary	D_2	118.40	+.13	118.53
Rotating	D_2	118.65	—.13	118.52

The values of $2x$, remembering that a centimeter scale was used, are again surprisingly good. The shift is computed by the above equation. It may be eliminated in the mean of the two methods. The lens L' may be more easily and firmly fixed than L.

7. *Collimator Method.*—The objection to the above single-lens methods is the fact that the whole spectrum is not in sharp focus at once. Their advantage is the simplicity of the means employed. If a lens at L' and at L are used together, the former as a collimator (achromatic) and with a focal distance of about 50 cm., and the latter (focal distance to be large, say 150 cm.) as the objective of a telescope, all the above difficulties disappear and the magnification may be made even excessively large. The whole spectrum is brilliantly in focus at once and the corrections for the shift of lines due to the plates of the grating vanish. Both methods for stationary and rotating gratings give identical results. The adjustments are easy and certain, for with sunlight (or lamplight in the dark) the image of the slit may be reflected back from the plate of the grating on the plane of the slit itself, while at the same time the transmitted image may be equally sharply adjusted on the focal plane of the eye-piece. It is therefore merely necessary to place the plane of spectra horizontal. Clearly a' and a'' are all infinite.

In this method the slide S and D are clamped at the focal distance apart, so that flame, etc., slit, collimator lens and grating move together. The grating may or may not be revoluble with the lens L on the axis a.

8. *Data for the Collimator Method.*—The following data chosen at random may be discussed. The results were obtained at different times and under different conditions. The grating nominally contained about 15,050 lines per inch. The efficient rod length ab was $R = 169.4$ cm. Hence if $1/C = 15{,}050 \times .3937 \times 338.8$, the wavelength $\lambda = C \cdot 2x$ cm.

Grating.	Lines.	$2x'$	$2x$
Stationary	D_2	118.30	118.19
Rotating	D_2	118.08	118.19
Stationary	D_2	118.27	118.16
Rotating	D_2	118.05	118.16

Rowland's value of D_2 is 58.92×10^{-6} cm.; the mean of the two values of $2x$ just stated will give 58.87×10^{-6} cm. The difference may be due either to the assumed grating space, or to the value of R inserted, neither of which were reliable absolutely to much within .1 per cent.

Curious enough an apparent shift effect remains in the values of $2x$ for stationary and rotating grating, as if the collimation were imperfect. The reason for this is not clear, though it must in any case be eliminated in the mean result. Possibly the friction involved in the simultaneous motion of three slides is not negligible and may leave the system under slight strain equivalent to a small lateral shift of the slit.

9. *Discussion.*—The chief discrepancy is the difference of values for $2x$ in the single lens system (for D_2, 118.7 and 118.5 cm., respectively) as compared with a double lens system (for D_2, 118.2 cm.) amounting to .2 to .4 per cent. For any given method this difference is consistently maintained. It does not, therefore, seem to be mere chance.

We have for this reason computed all the data involved for a fixed grating 5 cm. in width, in the two extreme positions, Fig. 5, the ray being normally incident at the left hand and the right hand edge respectively for the method of § 6. The meaning of the symbols is clear from Fig. 5, S being the virtual source, g the grating, e the diffraction conjugate focus of S for normal incidence, so that $b=r$ is the fixed length of rod carrying grating and eye-piece. It is almost sufficient to assume that all diffracted rays b' to b'' are directed towards e, in which case equations (1) would hold; but this will not bring out the divergence in question. They were therefore not used. Hence the following equations (2) to (5) successively apply where d is the grating space.

(1) $\cot\theta' = (b/g + \sin\theta)/\cos\theta;\ \cot\theta'' = (b/g - \sin\theta)/\cos\theta;$

(2) $a = b/\cos^2\theta;\ \ a' = a'' = \sqrt{g^2 + a^2};$

(3) $\sin i' = \sin i'' = g/a';$

(4) $-\sin i' + \sin(\theta + \theta') = \lambda/d;\ \ \sin\theta = \lambda/d;$
$\sin i'' + \sin(\theta - \theta'') = \lambda/d;$

(5) $\cos^2 i'/a' = \cos^2(\theta + \theta')/b';\ \ \cos^2 i''/a'' = \cos^2(\theta - \theta'')/b''.$

Since θ, g, λ, d, b, are given θ' and θ'' are found in equation (4), apart from signs. If δ_1 and δ_1'' be the distance apart of the projections of the extremities of b' and b, b and b'', respectively, on the line x,

$$(6)\quad \begin{aligned} \delta_1' &= g + (b - b')\sin\theta - b'\sin i' \\ \delta_1'' &= g + (b'' - b)\sin\theta - b''\sin i'' \end{aligned}$$

If δ_2' and δ_2'' be the distance apart of the intersections of the prolongation of b' and b, b and b'', respectively, with the line x,

$$(7)\quad \begin{aligned} \delta_2' &= \sin(\theta + \theta')(b\cos\theta/\cos(\theta + \theta') - b') \\ \delta_2'' &= \sin(\theta - \theta'')(b'' - b\cos\theta/\cos(\theta - \theta'')) \end{aligned}$$

Given $b = 169.4$ cm., $\theta = 20^\circ\ 22'$, about for sodium, $g = 5$ cm., the following values are obtained:

$$\begin{array}{rrr} \theta' = 1^\circ\ 36', & a = 192.7\text{ cm.}, & b' = 166.0\text{ cm.}, \\ \theta'' = 1^\circ\ 34', & a' = a'' = 192.8\text{ cm.}, & r = b = 169.4\text{ cm.}, \\ i' = i'' = 1^\circ\ 30', & & b'' = 172.4\text{ cm.}, \end{array}$$

whence

$$\delta_1' = 1.92\text{ cm.},\quad \delta_2'' = 1.74\text{ cm.}$$

These limits are surprisingly wide. If, however, they should be quite wiped out on focusing, for any group of rays and symmetrical observations on the two sides of the apparatus, this would be no source of discrepancy. The effect of focusing the two parts of the grating may, in the first instance, be considered as a prolongation of b' till it cuts x, together with the corresponding points for the intersection of b'' with x. Thus the values δ_2' and δ_2'' are here in question and they are

$$\delta_2' = 1.97\text{ cm.},\qquad \delta_2' - \delta_1' = .05\text{ cm.}$$

whence

$$\delta_2'' = 1.65\text{ cm.},\qquad \delta_1'' - \delta_2 = .09\text{ cm.}$$

are the conjugate foci for the extreme rays of the grating, respectively, beyond the conjugate focus of the middle or normal rays b, on x. Hence the mean of the extreme rays lies at .07 cm. beyond

(greater θ) the normal ray and the λ found in the first instance is too large as compared with the true value for the normal ray.

The datum .07 cm. may be taken as the excess of $2x$, corresponding to the excess of angle for a grating one half as wide and observed on both sides ($2x$), as was actually the case. Finally; since the whole of the grating is not in focus at once a correction less than .07 cm. for $2x$ must clearly be in question. This is quite below the difference of several millimeters brought out in §§ 4 and 6.

To make this point additionally sure and avoid the assumption of the last paragraph, we will compute the conjugate focus of the central ray (different angles θ) on the b' focal plane parallel to the grating and to x and on the b'' focal plane parallel to x. The computation is simpler if the central ray is thus focused, than if the extreme rays are focused on the x plane. The distance apart will be

$$\delta_3' = g - b' \cos(\theta + \theta')(\tan(\theta + \theta') - \tan\theta),$$
$$\delta_3'' = g - b'' \cos(\theta - \theta'')(\tan\theta - \tan(\theta - \theta'')).$$

Inserting the results for θ, θ_1', θ_1'', b', b'', g,

$$\delta_3' = .06, \quad \delta_3'' = -.04.$$

Both the b foci thus correspond to large angles. Their mean, however, may be considered as vanishing on the intermediate x plane.

Thus it is clear that the effect of focusing is without influence on the diffraction angle and much within the limits of observation. It is therefore probable that the residual discrepancy in the three methods is referable to a lateral motion of the slit itself due to insufficient symmetry of the slides AA and BB in the above adjustment. This agrees, moreover, with the residual shift observed in the case of parallel rays in § 8.

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THE ELECTRON METHOD OF STANDARDIZING THE CORONAS OF CLOUDY CONDENSATION.

By CARL BARUS.

(*Read April 24, 1909.*)

1. *Introductory.*—Last year I published some preliminary experiments[1] in which the coronal display of the fog chamber was standardized by aid of the value of Thomson's electron, $10^{10}e = 3.4$ electrostatic units, and of the known velocity of the ions. Later similar experiments were made in terms of the former datum and the decay constants of the ions, though this method is not here to be considered. In the experiments in question a separate leaded condenser was used to determine the ionization, while the nucleation was measured in a cylindrical fog chamber. The data, though necessarily rough, owing to the dampness of the room in the summer time, when used for the determination of e by aid of my earlier and independent constants of coronas, nevertheless gave a series of promising values. In the paper cited it was assumed that the whole current due to both positive and negative ions is measured. If, however, the current observed is due to negative ions, while the negative ions only were caught in the fog chamber used, as now appears probable, then the data would be ($\dot{V}$ denoting the fall of potential per second, dV/dr the average field, all referred to volts, N the number of nuclei (negative ions), per cubic centimeter).

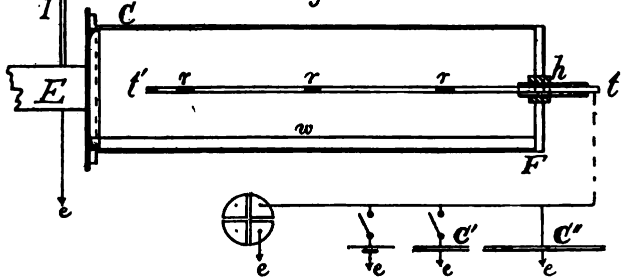
dV/dr	$10^3\dot{V}/V$	N	$10^{10}e$
1.0	40	150,000	3.3
.7	50	185,000	3.2
.7	60	210,000	3.7
1.2	137	570,000	2.9

where the velocity of negative ions in a unit field of dry air is taken as $v = 1.87$ cm./sec.

[1] *American Journal of Science,* XXVI., 1908, p. 87; *idem,* p. 324.

In the following experiments I have returned to the measurements of N in terms of e and the velocities of the ions, modifying the method by using the cylindrical fog chamber both as an electrical condenser for the measurement of current, as well as for the specification of the number of ions in action by aid of the coronas of cloudy condensation.

Fig. 1



2. *Apparatus*.—This consists of a cylinder of glass C, F, about 45 cm. long, 13.4 cm. internal diameter, closed at one end F and provided with a brass cap C, with exhaust E and influx attachments I, in the usual way. There is a layer of water w at the bottom. The glass must be scrupulously clean within; and this is best secured by scouring with a probang of soft rubber under water, until the water adheres as an even film on shaking. The fog chamber is put to earth, as at e.

The end F is perforated at h, to receive the aluminum tube tt', closed at t' and open at t, 40 cm. long and .64 cm. external diameter. Sealed tubelets of radium r, r, ... may be placed at intervals within this tube to ionize the surrounding wet air. The walls being about .1 cm. thick, β and γ rays are wholly in question. Neither emanation nor α rays escaped the double thickness of aluminum. The tube tt' is grasped at t by a sheath of hard rubber with an annular air space and fixed in place by a rubber cork. If care be taken to keep the tube in dry air except when in use, there is no conduction leakage of consequence.

The end t, moreover, is placed in connection with a Dolezalek electrometer, by aid of a thin wire (not shown) running axially

within an earthed tin drain pipe and away from the fog chamber, to escape the action of γ rays as much as possible. In fact their combined effect does not exceed 2 per cent. and is determined in special measurements.

The keys to the electrometer,[2] etc., were all placed on pillars of hard rubber and actuated by long wooden rods from a distance. So far as possible the electrical wires of the room were surrounded by earthed pipes, but it was not practicable to carry this out completely so that a method of correction appears in the work below. Even when the electric lighting circuit was completely cut out, the electrostatic drift in question remained.

The measurements were standardized and the electric system charged by a Carhart-Clarke cell.

The radium tubelets used were as follows:

No. I,	100 milligrams,	strength	10,000 ×
No. II,	10 milligrams,	strength	200,000 ×
No. III,	100 milligrams,	strength	10,000 ×
No. IV,	100 milligrams,	strength	7,000 ×
No. V,	100 milligrams,	strength	20,000 ×

3. *Electrical Condensers.*—To give the fall of potential a suitably small value relatively to the period of the damped drop of the needle, a number of auxiliary condensers, C', C'', Fig. 1, are needed. It suffices, however, to measure three capacities, viz.,

1. That of the cored fog chamber alone, c;
2. That of a relatively large auxiliary condenser, including the electrometer, the piped wires and the fog chamber, $C'' + c$;
3. That of a standard condenser, C', for reference.

In the present paper C' was computed by the equation

$$C' = \frac{A}{4\pi d}\left(1 + \frac{1}{\sqrt{\pi A}}\left(d + d \ln \frac{16\sqrt{\pi A}(d + d')}{d^2} + d' \ln \frac{d + d'}{d}\right)\right)$$

where A is the area, d the distance apart and d' the thickness of

[2] The disposition of condensers C', C'', cell, etc., earthed at e is suggested in Fig. 1.

the brass plates. Since A is equal 315 sq. cm., $d = .082$ cm., $d' = .67$ cm.,

$$C' = 305.6(1 + .0784) = 330 \text{ cm.}$$

This value will suffice for the present purposes, though it needs further correction by comparison with a standard condenser, not now at hand.

A special key was provided (Fig. 1) whereby C' could be switched into the electrometer system or out of it and put to earth. Hence in a series of successive discharges

$$(C'' + c)V = (C'' + C' + c)V',$$
$$(C'' + c)V' = (C'' + C' + c)V'',$$

etc., so that for n discharges, if the residual potential is V_n

$$V(C'' + c)^n = V_n(C'' + C' + c)^n,$$

from which the total capacity $C = C'' + C' + c$ is determinable in terms of C'. The results were:

Positive charge, $C'' + C' + c = 1{,}445$, 1,443, 1,422,
Negative charge, $C'' + C + c =$ 1,482, 1,480,
Mean $C = 1{,}459$,

the experiments alternating from positive to negative charge, because of the marked drift by the electrometer system when isolated from the cell, as already specified. To measure the small capacities c, of the fog chamber, the same method with *ten* discharges suffices, if C'' is excluded and C' retained. Thus the data were successively found,

+ Charge,	$c = 11.8$	12.4	12.2	12.9,
— Charge,	$c = 10.8$	10.4	11.1	11.5,
Mean	$c = 11.3$	11.4	11.6	11.2,

eliminating the drift in the final mean, $c = 11.4$.

Since the capacity c in terms of the effective internal radius R_2 and external radius R_1 the length l of the clindrical condenser may be written

$$\frac{1}{l} \log \frac{R_1}{R_2} = \frac{1}{2 \times 2.3 \times c},$$

the constant c furnishes a mean value for the factor on the left. The ratio of 4.6 c to the measured value of $(\log R_1/R_2)/l$ was .568, a reduction factor used throughout the tables below.

4. *Method Pursued.*—If C is equal to $C''+C'+c$ we may write the equation for the negative ionization N (positive charge)

$$N=\frac{C\ln R_1/R_2}{600\pi lve}\cdot\frac{d(\ln V)}{dt}=\kappa\frac{d(\ln V)}{dt},$$

where R_1, R_2 and l are the effective radii and length of the condenser, $10^{10}e=3.4$, $v=1.51$ cm./sec., and $u=1.37$ cm./sec., the velocity of the negative and positive ions in the unit field, volt/cm., in case of moist air. The factor $(\ln R_1/R_2)/l$ is replaced by $1/2C$, as specified in § 3, which must here be regarded as an adequate correction for the ends and the imperfect cylindricity of the condenser fog chamber.

Similarly the equation for the positive ionization is (negative charge),

$$N'=\frac{C\ln R_1/R_2}{600\pi lue}\frac{d(\ln V')}{dt}=\kappa'\frac{d(\ln V')}{dt}$$

and the total ionization is therefore $N+N'$.

The experiments below will show that even if the fog chamber is put to earth, there is a drift towards negative potential, sufficiently steady to be eliminated in the mean results. Hence if V_0 be the effective negative potential of the wet glass envelope we may write tentatively,

$$N=\kappa\frac{d\ln(V-V_0)}{dt}\quad\text{or}\quad N\left(1-\frac{V_0}{V}\right)=\kappa\frac{d(\ln V)}{dt}$$

where V_0 is intrinsically negative.

Similarly,

$$N'\left(1+\frac{V_0}{V}\right)=\kappa'\frac{d(\ln V')}{dt}.$$

Hence if $V=V'$, $N+N'$ the total ionization is again

$$\frac{d}{dt}(\kappa\ln V+\kappa'\ln V').$$

Direct experiments, however, show that the drift results from

the influx of a high permanent positive voltage. Curiously enough even when the lighting circuit is cut out, the effect remained with undiminished intensity. It will appear elsewhere, that in the absence of radium and of initial charge in the condenser, the equation $I_0 = C\dot{V}_0$ where $\dot{V}_0$ for any given ionization is a constant negative quantity, applies very closely within the limits of measurable $\dot{V}_0$ values. Hence in the presence of radium in the core of the cylindrical fog chamber and a positive charge,

$$I_0 + 600\pi lVNev/(\ln R_1/R_2) = C\dot{V}.$$

Thus in this case

$$NV = \kappa d(V - V_0)/dt; \quad -N'V' = \kappa' d(-V' - V_0)/dt,$$

and for the same $V = V'$, to a first approximation

$$N + N' = d(\kappa \ln V + \kappa' \ln V')_{V=V'}/dt,$$

as before. If the equation for N is integrated and $N/\kappa = K$, since $I_0 = C\dot{V}_0$, $\dot{V}_0$ being intrinsically negative,

$$V = \epsilon^{-Kt}(V_c - \dot{V}_0/K) + \dot{V}_0/K; \quad V' = \epsilon^{-K't}(V_c' + V_0/K') - \dot{V}_0/K',$$

where V_c and V_c' are the initial positive and negative potentials. The constant $\dot{V}_0$ increases with the strength of the ionization but has a fixed value for a given ionization.

5. *Data: High Ionization: Currents*—The tables[3] investigated contain the mean potentials $\bar{V}$, the positive and negative logarithmic currents $d(\log V)/dt$ (apart from the constant), the apparent nucleation N positive and N' negative, computed from these data and additional information as to conduction leakage and effect of γ rays. In most of the cases the corresponding logarithmic currents due to γ rays outside the fog chamber was carefully measured in the same units, by placing a short hard-rubber rod between the end t of the aluminum tube, Fig. 1, and the wire leading to the electrometer. This cuts out the fog chamber but leaves the whole remaining circuit undisturbed. Similarly the leak value of $d(\log V)/dt$ in the absence of radium and due to mere conduction of moist parts is always quite negligible. Thus in the data in

[3] The tables will be removed for brevity, as Figs. 2–4 sufficiently reproduce the data.

question for relative logarithmic currents of the order of .035, the γ ray effect is .0010, the conduction leakage smaller than .0001. The other extreme, *i. e.*, the value of $d(\log V)/dt$ for the freely falling needle is about .1 in the same units. Hence it follows that if the needle falls faster than would be quite trustworthy, the auxiliary capacity selected is too small. The time interval between observations for V was 4 sec., throughout.

6. *The Same: Coronas.*—These results (to be given in Figs. 2*a* and 2) contain the data for the maximum ionizations obtainable with the radium tubelets I., II., III., IV., V. at my disposal. The corresponding corona was a large orange-yellow type, representing (in my former reductions) 506,000 nuclei in the exhausted fog chamber. I have supposed this to be equivalent to 653,000 when the fog chamber is at atmospheric pressure, seeing that the coronas are actually displaced during exhaustion; *i. e.*, at the maximum ionization does not coincide in the position with the largest corona on exhaustion,[4] but is displaced in the direction of the exhaust currents. The observation would seem to mean that exhaustion is more rapid than the reproduction of ions to restock the region of dilatation. In general this inherent discrepancy of a marked distribution of ionization increasing from end to end of the fog chamber is still outstanding. It is partially allowed for since the observations are made near the middle of the chamber where the average conditions supervene.

7. *The Same: Summary.*—The data given in Fig. 2*a* merely show the fall of potential in scale readings, in the successive observations 4 seconds apart, for positive and negative charges. Fig. 2 gives the corresponding positive and negative *apparent ionizations.* If the two curves between .8 and 1.2 volts be considered, the mean ionization of each is

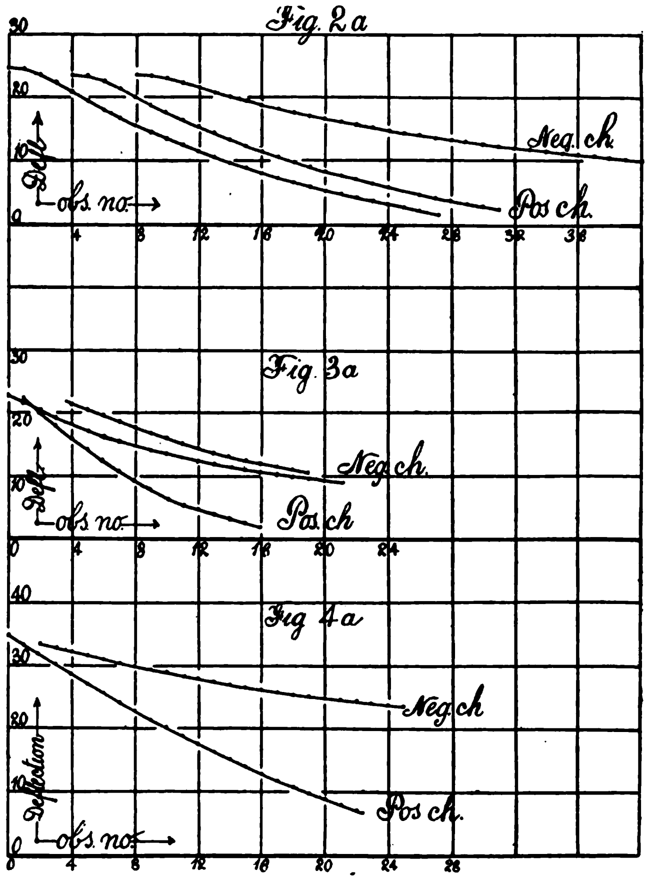
Apparent positive ions (negative charge), $N =$	540,000.
Apparent negative ions (positive charge), $N' =$	1,164,000.
Total true ionization, $N + N'$	= 1,704,000.
Total nuclei caught,	650,000.

It will be seen that $N + N'$ is the true total ionization, positive

[4] See papers cited; also *Science*, XXVIII., p. 26, 1908.

and negative, if $10^{10}e = 3.4$. Only 65/170, or about 38 per cent., of this is actually caught in the given fog chamber on exhaustion, provided the old coronal values are corect.

If, however, it is assumed that negative ions only are caught



during exhaustion in the fog chamber in question, then the value of the electron would be

$$10^{10}e = 3.4 \times 2.62 \times \tfrac{1}{2} = 4.4 \text{ electrostatic units.}$$

The irregularities of the curves, Fig. 2, are due in part to fluctuations of the drift and in part to errors inevitable in derivations so

close together; but such errors necessarily compensated each other in the mean values.

10. *Data: Moderate Ionization: Electrical Currents.*—These results were obtained by placing but one radium tubelet, No. IV., in the aluminum tube tt' of the condenser-fog-chamber. The data were found in the same way as in the above. $N = \kappa d(\log V)/dt$, as usual.

Both positive and negative currents were observed in succession and the true total ionization is $N + N'$ as before. Moreover, the capacity of the condensers were widely varied, 410 to 1,459 cm., without showing serious divergences.

11. *The Same: Coronas.*—At a fall of pressure of 21 cm. (and somewhat below) or $\delta p/p = .27$, the nucleation was stationary and equal to $N = 113{,}000$ in the exhausted fog chamber. At atmospheric pressure therefore $113{,}000 \times 1.37 = 154{,}000$ nuclei should have been present. The effect of a charge on the core of the condenser did not appreciably diminish the nucleation.

12. *The Same: Summary.*—The successive observations in scale parts at intervals, 30 seconds apart, are shown in Fig. 3*a*, the slopes only being of interest. The apparent values of N are given in Fig. 3. All the four series show about the same drift, even though taken many days apart. The condenser effect (excessive rapidity of needle) may be considered eliminated for capacities greater than 500 cm.

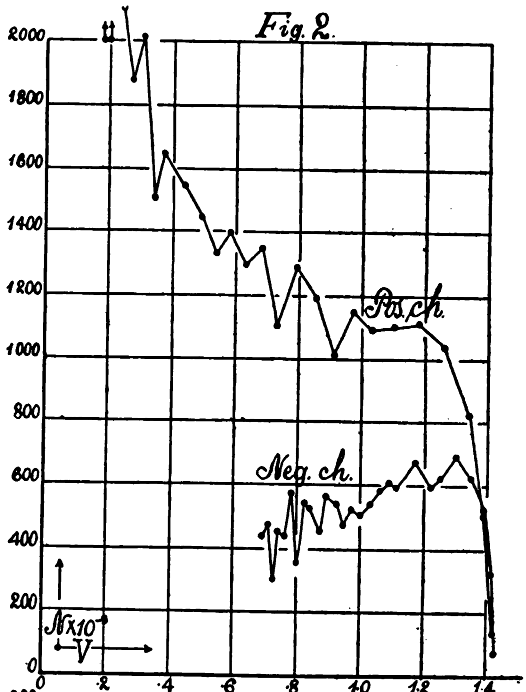
By averaging the ionizations between $\overline{V} = .6$ and $\overline{V} = 1.24$ in both curves the data found are as follows:

Apparent negative ions, N	$= 278{,}000$.
Apparent positive ions, N'	$= 107{,}000$.
True total ions, $N + N'$	$= 385{,}000$.
Total nuclei,	180,000.

Hence about 47 per cent. of all the ions were caught on exhaustion, if the values of u, v, e, N, inserted, are correct. Supposing that negative ions only are caught in the above fog chamber, the value of the electron would be

$$10^{10}e = 3.4 \times 2.14 \times \tfrac{1}{2} = 3.6 \text{ electrostatic units.}$$

Fig. 2.



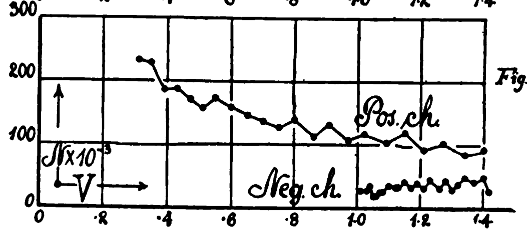
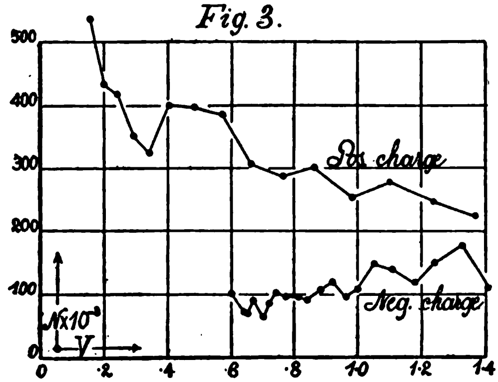


Fig. 4.

Fig. 3.



13. *Data: Small Ionization: Electric Currents.*—In the next series of experiments the aluminum tube tt', Fig. 1, was surrounded by a lead tube with walls .117 cm. thick, leaving the γ rays only effective and these much reduced in intensity. The data are sufficiently given in the following charts.

14. *The Same: Coronas.*—The coronas found at a drop of pressure similar to the above $\delta p/p = .300$, corresponded in my tables to 46,200 nuclei in the exhausted fog chamber. Hence at atmospheric pressure there should have been 64,000. The effect of charging the core was not definite.

15. *The Same: Summary.*—The drop of potential in scale parts, in successive intervals 30 cm. apart, is given in Fig. 4*a*, showing how much slower the negative charges are lost than the positive charges. The apparent values of N are given in Fig. 4, to which remarks similar to those already made are applicable. There is the usual drift and the usual temporary fluctuation.

If the mean data be taken between $V = 1.1$ and 1.4 volts, the results are

Apparent positive ions, N'	$=$	37,000.
Apparent negative ions, N	$=$	98,000.
True total ionization, $N + N'$	$=$	135,000.
Total nuclei caught,		60,000.

It follows, then, that about 44 per cent. of the total ionization computed from $10^{10}e = 3.4$, u and v, is caught on condensation.

If we suppose the negative ions only are caught in the above fog chamber the electron value is

$$e \times 10^{10} = 3.4 \times 2.3 \times \tfrac{1}{2} = 3.9 \text{ electrostatic units.}$$

Conclusion.—Supposing the electron value to be $10^{10}e = 3.4$ electrostatic units as before, the normal velocities of the ions in wet air to be $u = 1.37$, $v = 1.51$ cm./sec., in the volt/cm. field, the coronal equivalent of the ions caught in the above fog chamber is in the several cases,

Total ions, 1,700,000,	Total nuclei, 38 per cent.
385,000,	47 per cent.
135,000,	44 per cent.

When N is 1,700,000 the coronas are too diffuse for sharp specification. If it is assumed that negative ions only are caught, and if the nucleations corresponding to the coronas seen in the given fog chamber be taken as developed in my earlier work, then for

$$N + N' = 1{,}700{,}000, \quad 385{,}000, \quad 135{,}000,$$

the electron values are

$$10^{10}e = 4.4, \quad 3.6, \quad 3.9,$$

electrostatic units.

With regard to the two parts of this paper that need revision the first, the comparison of the computed condenser capacity C' with a standard, is a minor matter; but the other, *i. e.*, the marked distribution of ionization along the axis of the fog chamber, will need further inquiry. In the direction of the exhaustion the amount of ionization may vary in the ratio of more than 1 to 2, in a fog chamber of about one half meter of length; and this under conditions where there should apparently be no variations and irrespective of the production of radiation from within or from outside of the fog chamber.

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THE ELECTROMETRIC MEASUREMENT OF THE VOLTAIC POTENTIAL DIFFERENCE, BETWEEN THE TWO CONDUCTORS OF A CONDENSER, CONTAINING A HIGHLY IONIZED MEDIUM.

By CARL BARUS.

(*Read April 24, 1909.*)

1. *Introductory.*—The difficulties encountered in the preceding paper (§ 4), were made the subject of direct investigation by replacing the fog chamber with a metallic cylindrical condenser, the core of which was an aluminum tube, 50 cm. long and .63 cm. in diameter, the shell a brass tube, 50 cm. long and 2.1 cm. in diameter, coaxial with the former. Sealed radium tubelets could be placed within the aluminum tube, or withdrawn from it. Moreover, either the outer coat or the core of the condenser could be joined in turn with the Dolezalek electrometer, the other being put to earth. The conducting system now appears as follows (Fig. 1), *C* being the outer coat or brass shell, *A* the aluminum core and *r* the radium tubes in the cylindrical core. Conductors are earthed at *e*. *BB* show the metallic connections with the auxiliary condensers *C'*, *C"*. *E* is one of the insulated quadrants of the electrometer with the highly charged needle *N*, *E* being virtually also a condenser.

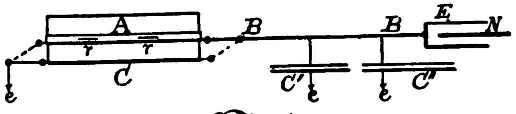


Fig. 1

A Clark standard cell may be inserted for standardization, but it is otherwise withdrawn.

Direct experiment showed the self charging tendencies to come apparantly from the highly charged needle *N*, as if positive ions were loged into the conductor *EBBA* for a positive needle, negative ions

for a negative needle. In addition to this however there is a *voltaic* difference, aluminum-brass, at AC when radium is in place and the medium therefore highly ionized. The latter potentials are usually negligible. These are the chief electromotive forces, the first very high (150 volts) and in a weakly ionized medium; the other low (.2 volt) but in an intensely ionized medium: thus they may produce equal currents. Other voltages such as the room potential may be operative, but their effect is secondary. If the capacities C', C'', are successively removed the electrometer current increases proportionately, showing its origin to be directed from the needle toward the insulated or non-earthed pair of quadrants.

If the condenser metals are reversed (see Fig. 1), the voltaic couple is reversed. This makes it possible to obtain both the voltaic contact potential and the ionization in the condenser C, from a pair of commutated measurements.

2. *Theory.*—Let V_n be the potential at the electrometer, V_c the voltaic potential difference of the two metals of the condenser, V the potential of the insulated conductor BB, measured by the electrometer. Let n be the hypothetical ionization in the electrometer, N the (radium) ionization in the condenser (length l, radii R_1, R_2). Let C be the total capacity of the systems $CBBE$. Then

$$\dot{V} = A(V_n - V)n - \frac{600\pi l N e v}{C \ln R_1/R_2}(V - V_c)$$

where A is a constant, u and v the normal velocities of the positive and negative ions, e the charge of the electron. The needle is positively charged. This may be written

$$\dot{V} = \dot{V}_a - K(V - V_c),$$

where for $N = 0$, $K = 0$, or

$$\dot{V} = \dot{V}_a = A(V_n - V)n,$$

i. e., the current in the electrometer, observed in the absence of radium, from needle to quadrants. This is directly measurable with accuracy. It is nearly proportional to V_n since V is much within 1 per cent. of V_n.

The integral of this equation is, t being the time,

$$V = (\dot{V}_a/K)(1 - KV_c/\dot{V}_a)(1 - e^{-Kt}).$$

If now the needle is left positively charged, but the condenser metals exchanged (commutated), so that the aluminum core is earthed and the shell put in contact with the electrometer (see figure), the equation becomes

$$V' = (\dot{V}_a/K)(1 + KV_c/\dot{V}_a(1 - e^{-Kt})).$$

Let $\kappa = N/K$ and $\kappa' = N/K'$ where K' refers to the normal velocity of positive ions, u. Then if $k = V_c/\kappa\dot{V}_a$, and $k' = V_c/\kappa'\dot{V}_a$, similarly

$$\dot{V} = \dot{V}_a(1 - kN)e^{-Kt}.$$

$$\dot{V}' = \dot{V}_a(1 + kN)e^{-Kt}.$$

If the potential $V = V_\infty$ at $t = \infty$,

$$V_\infty = \kappa\dot{V}_a/N - V_c,\ V_\infty' = \kappa\dot{V}_a/N + V_c,$$

two equations from which both N and V_c may be found, if the limiting potentials V_∞, V_∞', and the electrometer current $\dot{V}_a$ are severally observed. If V_∞ is not obtainable, it may be computed from observations at t and $t_1 = 2t$, as

$$V_\infty = (2V - V_1)/V^2 \text{ and } V_\infty' = (2V' - V_1')/V'^2.$$

Here however there is a difficulty as the curves begin with a double inflection not yet expained. The times $t_1 = 2t$ must therefore be estimated from the observations beyond the double inflections; or the rearward prolongation of the curve for those observations, to meet the time axis. The initial tangents may be found in the same way, but this is not necessary since their values are, respectively,

$$\dot{V}_a(1 - kN) \text{ and } \dot{V}_a(1 + kN).$$

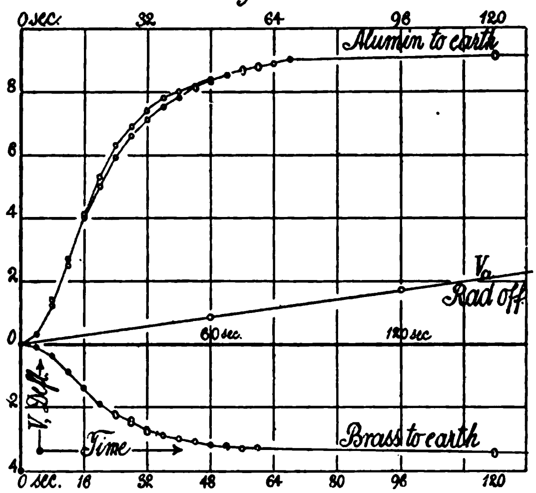
3. *Data: Origin of the Electrometer Current.*—The seat of the chief electromotive force in the electrometer follows from the following data, in which the capacities C, C', C'', Fig. 1, are successively removed. The currents increase in the same ratio as the reduction of capacities, E being that of the electrometer. The data are (potentials in scale parts where 1 cm. is equivalent to .0595 volt), $\dot{V}_a$ being the fall per second:

Capacities.	$\dot{V}_a$ in cm.	$\dot{V}_a$ in Volts.
$C + C' + C'' + E$	.14	.0083
$C' + C'' + E$	.15	.0089
$C' + E$	.58	.0345
E	4.3	.256

The change of voltage throughout the main contours of the curves is almost a linear variation with the lapse of time, except that at the beginning the motion is accelerated from rest as usual; for instance:

Time	0	4	8	12	16	20	24	28	32	60	sec.
V_a	0	.3	1.5	3.7	6.1	8.7	11.0	13.4	15.5	31.0	cm.

Fig 2



4. *Aluminum Tube Charged with Radium Tubelets I.–V.: Data.*—The air in the condenser C is now highly ionized and its voltage becomes appreciable. The data obtained are given in Fig. 2. The needle is positively charged, thus impelling positive charge toward the quadrants. In the four series of data observed the aluminum core of the condenser is twice joined to the electrometer, the brass shell being put to earth (series 1 and 4) and twice commutated (aluminum to earth series 2 and 3). The results are identical except that in series 3 the insulation was perhaps better, or V_a may have changed. The accelerated march of the needle from rest is obvious in both curves and is thus independent of the sign of the limiting voltage, V. It may be mere inertia, but it is of less consequence here because the initial data are not needed in the following computation.

5. *Results: Ionization, N. Voltaic Contact Potential Difference*[1] V_c.—The equations

$$V_c = \kappa \dot{V}_a/N - V\ ,$$
$$-V_c = \kappa \dot{V}_a/N - V_\infty',$$

may now be used to compute N and V_c. The constants are numerically (all in scale parts, 1 cm. equivalent to .0595 volt),

$$\kappa = 36.1 \times 10^6, \quad V_\infty = -3.45, \quad V_a = .142$$
$$\kappa' = 39.7 \times 10^6, \quad V_\infty' = 9.3,$$

Hence

$N = 876{,}000$ ions, either positive or negative,
$V_c = 6.37$ cms., or .376 volts.

[1] [The drift, V_a, which in the above experiments was eliminated by commutation, was eventually traced to a defect in the electrometer. It vanishes on replacing the given instrument by another. Data since obtained for Aluminium-Copper and Aluminium-Zinc condensers showed

Al-Cu, $V_c = .58$ volts,

Al-Zn, $V_c = .06$ volts,

or

Zn-Cu, .52 volts,

a result, however, which varied much with the surfaces, etc.] June, 1909.

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THE ABSORPTION SPECTRA OF VARIOUS POTASSIUM, URANYL, URANOUS AND NEODYMIUM SALTS IN SOLUTION AND THE EFFECT OF TEMPERATURE ON THE ABSORPTION SPECTRA OF CERTAIN COLORED SALTS IN SOLUTION.

(Plates VII. to XIV.)

By HARRY C. JONES and W. W. STRONG.

(*Read April 24, 1909.*)

(A report on part of the work on absorption spectra that is being carried out with the aid of a grant from the Carnegie Institution of Washington.)

Outline.

I. Experimental Methods.
II. Absorption Spectra of Potassium Salts in Aqueous Solutions.
III. Absorption Spectra of Uranyl Nitrate (under Different Conditions).
- (*a*) In Aqueous Solution.
- (*b*) In the Crystalline State.
- (*c*) As Effected by Dilution.
- (*d*) In Methyl Alcohol.
- (*e*) In Mixtures of Methyl Alcohol and Water.
- (*f*) In Ethyl Alcohol.
- (*g*) As an Anhydrous Salt.

IV. The Absorption Spectrum of Uranyl Bromide, Uranyl Acetate and Uranyl Sulphate.
- (*a*) Uranyl Bromide in Water.
- (*b*) Uranyl Acetate in Water.
- (*c*) The Uranyl Bands of the Acetate.
- (*d*) Uranyl Sulphate in Water.

V. The Absorption Spectrum of Neodymium Chloride in Glycerol.
VI. The Absorption Spectrum of Uranyl Chloride.
- (*a*) In Water.
- (*b*) As an Anhydrous Salt.
- (*c*) The Characteristic Bands in Water.
- (*d*) As Affected by Calcium and Aluminium Chlorides.
- (*e*) In Methyl Alcohol.

I. Experimental Methods.

On account of the large number of bands in the absorption spectra of uranium and the rare earth salts, a study of the absorption spectra of these salts is more interesting and more fruitful of results than the study of the absorption spectra of the ordinary colored salt like those of nickel or copper. The absorption spectra have been mapped for potassium ferricyanide, potassium ferrocyanide, potassium chromate, potassium dichromate, the acetate, bromide, chloride, nitrate and sulphate of uranyl in water, of uranyl acetate, nitrate and chloride in methyl alcohol, and of uranyl nitrate and chloride in ethyl alcohol. Beer's law has been tested for these salts as well as the effect of foreign substances on the absorption spectra. The absorption spectra of two uranous salts, the chloride and sulphate, have been photographed and the absorption spectra of neodymium chloride in pure glycerol and in mixtures of glycerol and water have been studied. In this work the methods used by Jones and Uhler[1] and Jones and Anderson[2] have in the main been employed.

The investigations on the effect of changes in temperature on the absorption spectra of solutions have been confined to different concentrations of aqueous solutions of the chloride, nitrate, acetate,

[1] Publication No. 60, Carnegie Institution of Washington.
[2] Publication No. 110, Carnegie Institution of Washington.

sulphate and sulphocyanate of cobalt, the chloride, acetate and sulplate of nickel, the chloride, sulphate and acetate of chromium, chrome alum, the nitrate and bromide of copper, uranous chloride, erbium chloride, the chloride and nitrate of præsodymium, the sulphate, acetate, chloride and nitrate of uranyl and the chloride, bromide and nitrate of neodymium. Spectrograms are made of the absorption spectra for a given concentration of a salt, keeping the thickness of layer constant for every 15° between 0° and 90° C.

To make a spectrogram light from a Nernst glower and from a spark is allowed to pass through the solution that is being investigated. It is then focused upon the slit of a spectroscope—and falling then on a concave grating, the light is spread out into a spectrum on the film upon which it is photographed. The films used were made by Wratten and Wainwright of Croyden, England, and were very uniformly sensitive to light from λ 2100 to λ 7200.

The sectional diagram (Fig. 1) will make the experimental arrangement of the apparatus clearer. *N* is a Nernst glower which is arranged to slide along the rod *AB*. *P* and *P′* are quartz prisms which are held by a lid *L*. The prism *P* is stationary, whereas the prism *P′* can be moved by the travelling carriage *E* back and forth through the trough *T* which contains the solution whose absorption spectrum is being investigated. *AB* is so inclined that the optical length of the light beam from *N* to *P′*, *P* and the concave mirror *M* shall be constant, whatever the length of the solution between *P* and *P′* may be. The greatest length of path *PP′* used was 200 mm. The hypothenuse faces of *P* and *P′* are backed by air films which are enclosed by glass plates cemented to the quartz prisms.

Considerable difficulty was experienced in finding a cement that would adhere to the polished quartz prisms at the higher temperatures. For aqueous solutions baked caoutchouc was found to work fairly well. *D* is a brass box holding the trough *T*. *D* is filled with oil and is placed in a water-bath whose temperature can be varied between 0° and 90° C. The path of a beam of light is then from the Nernst glower (*N*) or spark to the quartz prism *P′*. The light is totally reflected from the hypothenuse face of this prism through the solution to *P*. This prism also has its hypothenuse face backed by an air-film, so that the light is totally reflected upwards to the

concave speculum mirror at *M*. *M* focuses the light on the slit of the Rowland concave grating spectroscope, *G* being the grating and *C* the focal curve of the spectrum. The prism arrangement was designed by Dr. John A. Anderson.

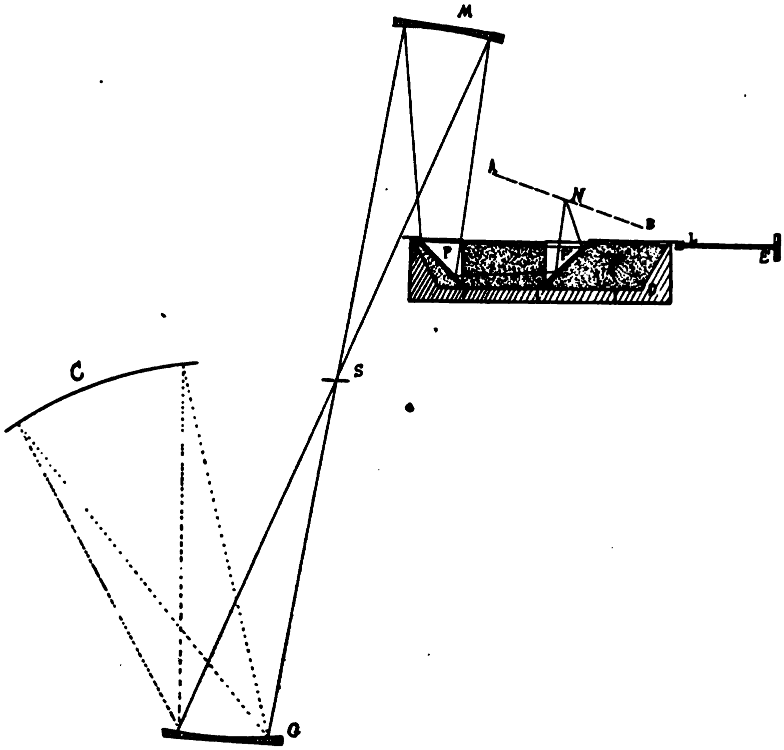


FIG. I.

This apparatus was found to work very well for aqueous solutions. Some evaporation took place at the higher temperatures, but distilled water was added in proper quantity and mixed with the solution so as to keep the concentration constant. By using troughs of different lengths it was possible to vary the length of salt solution through which the light beam passed from 1 to 200 mm. One inconvenience was experienced at low temperatures; moisture would sometimes condense upon the exposed prism faces. To overcome this an air blast was directed upon these faces and this helped very materially to prevent the condensation of moisture.

II. Absorption Spectra of Potassium Salts in Aqueous Solutions.

Most potassium salts in solution are colorless, and for this reason it is considered that the potassium atoms do not themselves absorb any light in the visible portion of the spectrum. Several colored potassium salts are known and the color of these is due in some way to the other atoms in the salt molecules. In the present work the absorption spectra of potassium ferricyanide, potassium ferrocyanide, potassium chromate and potassium dichromate have been studied.

Using a 3 mm. length of solution of potassium ferricyanide in water we find that for a normal concentration there is complete absorption of all the shorter wave-lengths of light beyond λ 4800. As the concentration is decreased the edge of transmission moves continually towards the violet. It should be noticed that the region between complete absorption and complete transmission for the more concentrated solutions is quite narrow, being less than 40 Ångström units; thus making solutions of this salt quite good screens for absorbing light. Continually decreasing the concentration we reach a 0.0156 normal solution, when a transmission band begins to appear. For a certain range of concentration there appears an absorption band in the region λ 4200. Further decrease in concentration results in increasing transmission throughout the violet and ultra-violet. For dilutions greater than 0.00195 normal there is almost complete transmission throughout the ultra-violet. Very faint bands appear in the regions $\lambda\lambda$ 2500 to 2600, $\lambda\lambda$ 2950 to 3050 and $\lambda\lambda$ 3200 and 3250.

Several spectrograms were made, keeping the product of concentration and depth of solution layer constant. In this case the spectrograms will be identical if Beer's law holds. Beer's law was found to hold according to this method of testing within the ranges of concentration over which the spectrum was mapped.

The absorption of aqueous solutions of potassium ferrocyanide was investigated in the same way. A half-normal solution 3 mm. deep shows that all light of shorter wave-length than λ 3950 is absorbed. Keeping the depth of layer the same, it is found that

with decrease in concentration the transmission gradually moves towards the ultra-violet, and for dilutions greater than 0.0078 normal there is transmission throughout the whole spectrum. Beer's law was found to hold.

A 2-normal aqueous solution of potassium chromate 3 mm. in thickness, shows complete transmission of wave-lengths greater than λ 4950. Decreasing the concentration causes the transmission to move gradually towards the violet and for a 0.01 normal solution a transmission band appears at λ 3100, or, in other words, there appears an absorption band whose center is about λ 3700. As the concentration decreases this absorption band fills up, the violet edge of the transmission band gradually pushes out into the ultra-violet, and for dilutions greater than 0.0005 normal there is complete transmission throughout the spectrum. Beer's law was found to hold for potassium chromate throughout the above ranges of concentration, except in the more concentrated solutions between 2 normal and 0.25 normal.

Potassium dichromate in water was found to have a much greater absorbing power than the solutions previously described. A one-third normal concentration absorbed all wave-lengths shorter than λ 5350. As the concentration is decreased the transmission extends farther and farther out into the violet. For a 0.0026 normal concentration a transmission band appears in the violet, thus giving an absorption band whose center is about λ 3800. As the concentration is further decreased transmission becomes greater and greater in the violet and ultra-violet, and is practically complete for a 0.0006 normal concentration. Beer's law has been tested between the above ranges of cencentration and has been found to hold.

In photometric measurements of Beer's law, the equation defining the quantities to be measured is:

$$J = J_0 \, 10.^{-Acl}$$

J_0 is the intensity of the light that enters the solution (neglecting any loss due to reflection), J the intensity of the light as it leaves the solution, c the concentration in gram molecules of the salt per liter of solution, l the thickness of layer and A a constant if Beer's law holds. Strictly speaking the above equation holds for mono-

chromatic light. For ordinary white light one would have to integrate this equation over the range of wave-lengths used. The equation would then have the form

$$J = J_0 \int_{\lambda_1}^{\lambda_2} e^{-\beta l c} d\lambda.$$

The quantity β is called the index of absorption and A the molecular extinction coefficient. If the absorption is proportionately greater in the more concentrated solutions, then Beer's law fails and A decreases inversely as the concentration.

From photometric measurements Settegast[3] and Sabatiér[4] conclude that the absorption spectrum of potassium dichromate is the same as that of chromic acid, and that the absorption spectrum of potassium chromate is entirely different. This is corroborated by the present work. Settegast finds that Beer's law does not hold for potassium chromate and potassium dichromate, the coefficient A decreasing with increasing concentration. Grünbaum[5] finds the following values of A and ϵ where $\epsilon = c/A$.

Potassium Dichromate.

λ	Value of A. $c = .034$	Value of A. $c = .0034$
509	62.4	58.0
521	28.7	26.2
538	7.24	6.2

It will be seen that the deviation here from Beer's law is in the opposite direction from that of Settegast. Grünbaum finds that ϵ and therefore A depends on the depth of layer.

An example will be given where the same concentration was used and different depths of the solution.

λ	Values of ϵ for $c = .0034$ 25 cm. layer.	12 cm. layer.	5 cm. layer.
521	.0758	.0818	.0884
521	.0761	.0830	.0897

Our work indicates that Beer's law holds for all small concentrations and usually the deviations for concentrated solutions is very

[3] *Wied. Ann.*, 7, pp. 242–271, 1879.
[4] *C. R.*, 103, pp. 49–52, 1886.
[5] *Ann. d. Phys.*, 12, pp. 1004, 1011, 1903.

small. Of the potassium salts above described, only potassium chromate between 2 normal and 0.25 normal showed any considerable deviation from Beer's law, and in this case the absorption of the concentrated solution was greater than would be expected if Beer's law held by about 40 Ångström units.

The present method is a very good qualitative test of Beer's law, and gives the results for each wave-length, whereas most photometric methods only give integrated results over a more or less wide region of wave-lengths.

III. Absorption Spectrum of Uranyl Nitrate under Different Conditions.

There are two groups of uranium salts, the uranyl salts containing the UO_2 group, and the uranous salts. The uranyl salts in solution are yellow and usually crystallize from aqueous solutions with a certain amount of water of crystallization; for example, at ordinary temperatures uranyl sulphate crystals have the composition $UO_2(SO_4)_2 3H_2O$. The uranous salts are intensely green and are very unstable, oxidizing very easily to the uranyl condition. Uranous sulphate crystals have the composition $U(SO_4)_2 9H_2O$.

(a) *Uranyl Nitrate in Aqueous Solution.*

The spectrum of uranyl nitrate in water is a typical example of the uranyl salts. Using a depth of solution of 3 mm. its absorption spectra was investigated between concentrations of 1.5 normal to 0.0234 normal. For the 1.5 normal solution the absorption consists of a band in the blue-violet and absorption throughout the ultra-violet portion of the spectrum. As the concentration decreases the blue-violet band fills up with transmission, and the ultra-violet absorption is pushed farther and farther out into the ultra-violet. The blue-violet band is practically gone at a concentration of 0.5 normal, and there is almost complete transmission throughout the ultra-violet for concentrations less than 0.02 normal.

During these changes in concentration a large number of bands about 50 Ångström units wide make their appearance. Near the edge of an absorption band these bands are relatively quite clear.

As the absorption edge recedes from the uranyl bands, the general transmission is so great as almost to entirely obscure them.

A, Plate I, represents the absorption spectra of an aqueous solution of uranyl nitrate of different depths of layer. The narrow and rather weak bands shown here are the uranyl bands. Twelve of these bands have been photographed. Starting at the band of longest wave-length they shall be designated by the letters *a, b, c, d,* etc. On account of the irregularity of the distribution of light in the spark spectrum and the small intensity of the uranyl bands, the Nernst glower was used as the source of light in the ultra-violet, and long exposures were made. A screen was used that cut out all wave-lengths greater than λ 4200. *A* represents a typical spectrogram of this kind. Starting with the spectrum strip at the top, the concentrations were 1.5 N, 1.1255 N, 0.75 N, 0.5 N, 0.375 N, 0.25 N, and 0.1875 N. The slit width was 0.08 mm. and the current through the Nernst glower 0.8 amperes. The spectra of wave-lengths greater than λ 4300 represent the absorption of a depth of layer of 15 mm.; the spectra of shorter wave-lengths represent the absorption of a depth of layer of 3 mm. The upper spectrum strip represents then the absorption spectrum of a 1.5 normal solution of uranyl chloride 15 mm. thick, exposure being made 1 min. to the Nernst glower. It will be seen that the uranyl *a* band comes out very strongly. The screen was then placed in the path of light and exposure of 5 minutes made to the violet and ultra-violet beyond λ 4300; a solution of uranyl nitrate of 1.5 normal concentration and 3 mm. depth of cell being in the path of the beam of light. This amount of uranyl nitrate absorbed practically all the light in this region. A very short exposure was afterwards made to the spark in the region λ 2600, in order to get a comparison spark spectrum in this region, so that the wave-lengths of the uranyl bands could be measured.

Throughout this work a comparison spark spectrum usually containing the very strong line λ 2478.8 was photographed on each spectrum strip. In measuring the uranyl bands all measurements were made from this line as a standard, and although the absolute wave-lengths of the uranyl bands may not be correct to within 20

Ångström units, yet their relative accuracy is probably correct to within less than 10 Ångström units for the finer bands.

The second spectrum strip from the top represents in the long wave-length end of the spectrum the absorption of a 15 mm. solution of a 1.125 normal solution of uranyl nitrate exposed 1 min. to the Nernst glower. The *a* band appears, although not nearly as intense as in the spectrum strip above. The region of shorter wave-lengths beyond λ 4300 represents the absorption of a 3 mm. depth of layer of a 1.125 normal concentration exposed 5 min. to the Nernst glower. A very faint transmission is shown in the region λ 3700. The ultra-violet line λ 2478.8 is shown in the comparison spark spectra. The other spectrum strips were made in a similar manner, using the concentrations given above.

By this method of exposing two new bands were detected in the ultra-violet. In aqueous solutions the intensities of the bands are much the same. In other solvents however and for other uranyl salts, the relative intensities of the bands change very greatly. In uranyl nitrate crystals the bands are even more closely related to each other than in aqueous solutions. The longer the wave-length of the band the more intense and wider it is as a rule. The position of the long wave-length bands in the orthorhombic uranyl nitrate crystals $UO_2(NO_3)_2 6H_2O$ is the same as the position of the bands for an aqueous solution. The wave-lengths of the bands are as follows:

	a	*b*	*c*	*d*	*e*	*f*	*g*	
Water Sol.	4860	4720	4540	4380	4290	4150	4020	Deussen.
Water Sol.	4870	4705	4550	4390		4155	4030	Jones and Strong.
Crystals	4870	4705	4500–4565	4405	4275	4170	4050	

	h	*i*	*j*	*k*	*l*	
Water Sol.	3870	3790	3690			Deussen.
Water Sol.	3905	3815	3710	3605	3515	Jones and Strong.
Crystals	3935	3830	(3720?)	3600		

In the original film from which *A*, Plate I, was made all these bands except *d* could be very distinctly seen. The bands of longer

wave-length are slightly wider. The *i* band is considerably weaker than its neighboring bands.

(*b*) *Absorption Spectrum of Uranyl Nitrate Crystals.*

In the aqueous solution there is no sign that the bands can be broken up. In the crystal spectrum this is not the case. The *a* band is narrow. The *b* band is also very narrow, about 15 Ångström units wide. A very faint band appears about λ 4650. The *c* band, on the other hand, is very wide, about 70 Ångström units, and is probably double. The *d* band is about 50 å. u. wide, and the *e* band is about 70 Ångström units wide and appears double. The *f* band is the most intense and is about 40 Å. u. wide. The bands *g, h, i* and *j* keep decreasing in intensity respectively. The above description is of a spectrogram taken of a crystal in Canada balsam, and of course the width of the bands varies with the time of exposure and various other things. The above spectrogram showed many details, however, that other spectrograms did not. It will thus be seen that the *a, b, c, d, j* and *k* bands of the solution agree fairly well with those of the crystal, and that the crystal bands *f, g, h* and *i* are shifted towards the red with reference to the bands in the aqueous solution.

(*c*) *Effect of Dilution upon the Uranyl Bands.*

The effect of dilution on the position and intensity of the blue-violet, the ultra-violet and the uranyl bands of the acetate, nitrate and sulphate of uranyl in water was tried. The absorption spectra of solutions of about 1 normal and 3 mm. depth of cell was photographed along by the side of the absorption spectra of the same salts of 0.008 normal concentration and 380 mm. depth of layer. The absorption consisted of the blue-violet band, the ultra-violet band and the *a, b, c, i, j* and *k* bands. Between the blue-violet and ultra-violet bands there was the transmission band containing *i, j* and *k*. For each of the three salts this transmission band was much weaker for the dilute solution, whereas in the cases of the sulphate and nitrate the long wave-length transmission edge of the blue-violet band was stronger for the more dilute solution. The opposite was true of the acetate solution. In the dilute solution of

the acetate the bands were more intense than for the more concentrated solution. There was no noticeable change in the position of the bands. Neither the intensity nor the position of the uranyl nitrate or the uranyl sulphate bands was changed by the above dilution.

A more detailed study was made as to whether Beer's law holds for uranyl nitrate and for the other uranyl salts. The method of taking the spectrograms is the same as that used for the potassium salts.

Beer's law was found to hold for dilute solutions of uranyl nitrate in water. When the concentration is greater than .5 normal the absorption is greater than it should be if Beer's law held.

(*d*) *Uranyl Nitrate in Methyl Alcohol.*

In methyl alcohol the general appearance of the absorption is very similar to that of the aqueous solution; the blue-violet, the ultra-violet, and uranyl bands appearing under the same general conditions that they appear for aqueous solutions. There is a very marked deviation from Beer's law for the more concentrated solutions, however; the absorption of concentrated solutions being greater than it would be if Beer's law held. The positions of the bands are quite different from the positions of the uranyl bands of the aqueous solution, or of the crystals, as shown by the following values:

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
λ	4930	4760	4610	4455	4325	4190	4070	3965	3855

(*e*) *Uranyl Nitrate in Mixtures of Methyl Alcohol and Water.*

In the previous work of Jones and Anderson[6] it was found that in some cases (for example neodymium chloride) a salt in water had a different set of absorption bands compared with the same salt in another solvent as, *e. g.*, methyl alcohol.

When the salt is dissolved in mixtures of these two solvents, say methyl alcohol and water, it was found that as the amount of one solvent, methyl alcohol for instance, decreased the methyl

[6] Publication No. 110, Carnegie Institution of Washington.

alcohol bands of the salt decreased in intensity, but did not change their position in the spectrum. At the same time the water bands of the salt became more intense. In the present work it is shown that the uranyl nitrate bands in pure water and in pure methyl alcohol occupy different positions. The problem to be investigated is to find out whether in mixtures of water and methyl alcohol, the uranyl bands will show a gradual shift, or whether the methyl alcohol uranyl bands and the water bands will both exist together; their relative intensities being proportional to the relative amounts of methyl alcohol and water. It was found that the two sets of bands exist together and that the methyl alcohol bands decrease in intensity quite rapidly with increase of water. The blue-violet band showed marked changes until the amount of water reached about 20 per cent. In this work the amount of uranyl nitrate in the path of the light was kept constant, and the only variable was the relative amounts of methyl alcohol and water. The above would indicate that uranyl nitrate in water is "hydrated" and in methyl alcohol it is "alcoholated." The above data indicate that the effect of "hydration" is much more persistent than that of "alcoholation." It is quite possible that this is due to a greater number of water molecules producing the hydration than there is methyl alcohol molecules taking part in alcoholation.

(*f*) *Uranyl Nitrate in Ethyl Alcohol.*

The absorption of uranyl nitrate in ethyl alcohol was mapped and the general characteristics were found to be the same as for the water and methyl alcohol solutions. A new band was found at λ 5200 which was about 50 Ångström units wide. All the uranyl bands were very faint and wide and therefore difficult to measure. Beer's law showed deviations similar to those found for the methyl alcohol solution. On account of the diffuseness of the bands no spectrograms were made of mixtures of water and ethyl alcohol. Following are approximately the positions of a few of the bands:

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
λ	5000	4800	4630	4475	4325	4180	4080	3970	3875

(*g*) *Absorption Spectrum of Anhydrous Uranyl Nitrate.*

When it was first discovered that the uranyl nitrate "water" bands were all shifted to the violet with reference to the bands of the other uranyl salts in water, as well as with reference to the uranyl nitrate bands in other solvents, it was thought that possibly it was more hydrated than the other salts in solution. The uranyl salts crystallize from water solutions at ordinary temperatures with the following composition: $UO_2(NO_3)_2.6H_2O$, $UO_2SO_4.3H_2O$, $UO_2(CH_3COO)_2.2H_2O$, and $UO_2Cl_2.H_2O$. This fact would favor the supposition that in solution the nitrate might be more hydrated than the other salts. The fact that the absorption of the aqueous solution of the nitrate and the crystallized salt was very much the same as far as the positions of the uranyl bands is concerned, also seemed to favor this view.

In this connection it was considered important to examine the absorption spectrum of the anhydrous uranyl nitrate. The salt was powdered and placed in a closed glass tube just above the slit of the spectroscope. The light of a Nernst glower was then focused upon the surface of the salt nearest the slit and an exposure of about three hours made. In this way we examine light that has penetrated a short distance into the powder and is then diffusely reflected.

The absorption spectrum was found to consist of quite a large number of bands, which seem quite different in many respects from those of the solution. The following are the approximate wave-lengths: $\lambda\lambda$ 4800, 4650, 4500, 4420, 4360, 4280, 4180 (broad), 4060 (broad), 3950 (broad), 3820 (broad), 3700 (narrow) and 3600 (narrow). The bands marked broad are from 50 to 60 Ångström units wide and the narrow bands about 20 Ångström units. If the first band is the *a* band, then the bands of the anhydrous salts are to the violet of the corresponding bands of the crystals and of the solution. If it is the *b* band the opposite is the case. On account of the smallness of the intensity of the bands it could not be settled whether λ 4800 is the *a* or the *b* band. Further investigation of this point will be made.

There are two difficulties to the above theory, difficulties for

which no explanation so far has been suggested. In the work on the effect of rise of temperature on the absorption spectrum it was found that the uranyl nitrate bands did not shift to the red. On the other hand, the uranyl sulphate and uranyl chloride bands were shifted to the red under the same conditions. (In these cases aqueous solutions were investigated.) If the uranyl nitrate bands owe their position to a large amount of hydration it would be expected that with rise in temperature they would be shifted towards the red more than the bands of the sulphate and chloride. Another difficulty is that of the effect of dilution. The greater the dilution the greater the dissociation, and, therefore, according to the theory of Arrhenius for very dilute solutions the UO_2 group should exist in the ionic condition and the absorption spectrum of all the salts should be the same, *i. e.*, the uranyl bands should then occupy the same positions independent of the kind of salt. No effect of this kind is to be noticed, as was shown above under the division describing the effect of dilution. It is intended to use much more dilute solutions in the future.

IV. The Absorption of Uranyl Bromide, Uranyl Acetate and Uranyl Sulphate.

(*a*) *Absorption Spectrum of Uranyl Bromide in Water.*

The absorption spectrum of uranyl bromide in water was mapped and found to be very similar to that of the nitrate. The ultra-violet, blue-violet and uranyl bands appear and are affected in the same manner as the same bands of the nitrate. Beer's law was found to hold. The uranyl bands were found to be much wider and more diffuse than in the case of the aqueous solution of the nitrate. The following are their approximate positions:

a	*b*	*c*	*d*	*e*	*f*
4880	4720	4560	4450	4280	4160

(*b*) *Uranyl Acetate in Water, Beer's Law.*

A spectogram was made to test whether Beer's law holds for an aqueous solution of uranyl acetate between the concentrations 0.25 normal and 0.031 normal. The spectrogram showed that there was a very great deviation from the law, and in the opposite direc-

tion to any deviation hitherto found either in this work or in that of Jones and Anderson or Jones and Uhler. The absorption of the more dilute solutions was found to be proportionately much greater than for the more concentrated solutions. A similar run was made for a solution of the acetate in methyl alcohol and a deviation from Beer's law in the same direction was found, although the amount was not so great in this case.

(*c*) *The Uranyl Bands of the Acetate.*

The following table gives the approximate wave-lengths of the uranyl bands of the acetate in water, in methyl and as the anhydrous powder.

Bands of Uranyl Acetate.

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
In Water	4910	4740	4595	4455	4310	4160	4070	3970	3830
In Methyl Alcohol	4900	4770	4600	4460	4320	4200	4090		
As Anhydrous Salt.	4910	4760	4610	4460	4330	4190	4070	3980	

From this table it seems that the positions of the bands of the acetate under these different conditions is about the same.

(*d*) *Absorption Spectrum of Uranyl Sulphate.*

The mapping of the absorption spectrum of uranyl sulphate in water showed that it was very much like that of the nitrate in water. As in the case of the nitrate the *i* band was much weaker than the adjacent bands. Beer's law was found to hold. The addition of a large amount of sulphuric acid was found to make the uranyl bands much sharper, but not to cause them to shift. Much more work will be done on the effect of strong acids on the uranyl bands. The following gives the wave-lengths of the sulphate bands:

a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*
4900	4740	4580	4460	4330	4200	4070	3970	3850	3740	3630	3530

V. The Absorption of Neodymium Chloride in Glycerol and Mixtures of Glycerol and Water.

The absorption spectrum of a glycerol solution of neodymium chloride is much like that of the aqueous solution in its general

characteristics, but when proper concentrations are used so as to bring out the fine bands it is found that the two spectra are entirely different. For example, the aqueous solution shows a very fine band at λ 4274. In the glycerol there is a band that on first sight appears exactly identical with this 4274 band. However, its wave-length is about λ 4287, and it has two extremely fine components on each side, one at λ 4273 and one at about λ 4300. The same is true throughout the spectrum.

In general, in mixtures of water and glycerol the appearances indicate that there are "glycerol" bands and "water" bands and as the amount of one solvent is increased, so are the bands corresponding to this solvent increased in intensity. Herein lies a very large field for investigation and considerably more work is being carried on here along these lines. The above described spectrum of the glycerol solution of neodymium indicates that glycerol has a a very great influence upon the vibrations of the electrons within the neodymium atom—and that this is due to a kind of "atmosphere" of glycerol about the neodymium atom. Jones and Anderson showed that alcohol has a similar effect, and that the "alcohol" bands were much less persistent than the water bands. Further work is being done upon the relative persistence of "water," "alcohol" and "glycerol" bands; also on the effects of foreign substances and rise of temperature upon these bands, both in the pure solvent and for mixtures of solvents.

VI. Absorption Spectrum of Uranyl Chloride.

The absorption spectrum of uranyl chloride was mapped for an aqueous solution, a methyl alcohol solution, an ethyl alcohol solution, a mixture of methyl alcohol and water, a mixture of methyl alcohol and calcium chloride, and a mixture of water and aluminium chloride.

(a) *The Absorption Spectrum of Uranyl Chloride in Water.*

The absorption spectrum of uranyl chloride in water was found to be very similar in general to that of the other uranyl salts. The uranyl bands were less sharp than the bands of the nitrate and sulphate in water. The wave-lengths of a few of the bands are as follows:

a	*b*	*c*	*d*	*e*	*f*	*g*
4920	4740	4560	4460	4315	4170	4025

(*b*) *Absorption Spectrum of Anhydrous Uranyl Chloride.*

The absorption spectrum of the anhydrous uranyl chloride was photographed in the same way as that of the anhydrous nitrate. The bands differ considerably from the bands of the aqueous solution, and one cannot tell very well whether they are identical with the corresponding *a, b, c,* etc., bands of the solution or not. Their wave-lengths are approximately as follows: $\lambda\lambda$ 4950 (narrow), 4860, 4765, 4700, 4615, 4540, 4460, 4320, 4290, 4160, 4050 and 3940.

(*c*) *The Characteristic Bands of Uranyl Chloride.*

In addition to the bands already described, uranyl chloride has several remarkably fine bands in the green. These bands are not more than 5 Ångström units wide and were first seen on spectrograms taken upon Whatten and Wainwright red sensitive films. They appear only for aqueous solutions, and the addition of calcium chloride or aluminium chloride causes them to disappear. They do not appear in alcoholic solutions. Aqueous solutions of uranyl sulphate show them very faintly. The wave-lengths are approximately as follows:

$\lambda\lambda$ 5185, 5200, 6000, 6020, 6040 and 6070.

These bands have never hitherto been noticed as absorption bands. H. Becquerel[7] gives quite a full set of measurements of the phosphorescent bands of various uranyl salts at room temperature and at the temperature of liquid air. Among the bands given for the double chloride of uranyl and potassium at room temperature are $\lambda\lambda$ 6070 to 6040, and $\lambda\lambda$ 5220 to 5193. Whether these correspond to the above absorption bands is quite difficult to say. Further work is being done in this direction.

(*d*) *Uranyl, Calcium and Aluminium Chlorides in Water.*

Spectograms were taken of aqueous solutions of a constant concentration of uranyl chloride to which varying amounts of calcium

[7] *C. R.*, t. 101, p. 1252, 1885; pp. 459 and 621, 1907.

chloride were added. The addition of calcium chloride causes the ultra-violet, the blue-violet band and the uranyl bands to widen generally. The effect upon the uranyl bands is however, very small. The effect of aluminium chloride, however, is very great. The two narrow and faint bands at λ 5200 only appear in the pure aqueous solution of uranyl chloride. The *a* band in the aqueous solution is about 60 Ångström units wide, and is almost as intense as the *b* band. The addition of aluminium chloride causes the band to become quite narrow, about 25 Ångström units wide. A slight addition of alminium chloride decreases the intensity of the band very considerably. Further increases in the amount of aluminium has very little effect. The addition of alminium also causes the bands to shift to the red; the shifts in some instances amounting to 25 Ångström units. The *b* and *c* bands have their intensity very greatly increased by the addition of aluminium chloride; and by making the solution about 2 normal of aluminium chloride these bands are shifted about 30 Ångström units to the red compared with the same bands for the pure uranyl chloride solution. The *d, e, f, g* and *h* bands are also increased in intensity, but are but very slightly shifted to the red. The *d* and *e* bands are widened so that they practically form a single band.

(*e*) *Absorption Spectrum of Uranyl Chloride in Methyl Alcohol.*

In the absorption spectrum of uranyl chloride in methyl alcohol the *a, b, c, d, e, f, g, h, i,* and *j* bands all appear, the *b* and *c* bands being the largest and most intense. The following are the approximate wave-lengths of the bands:

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*
Uranyl Chloride in Methyl Alcohol	4930	4760	4590	4465	4345	4220	4090	3980	3860	3760
Uranyl Nitrate in Methyl Alcohol	4930	4760	4610	4460	4325	4190	4070	3970	3855	
Uranyl Acetate in Methyl Alcohol	4900	4770	4600	4460	4320	4200	4090			

It is seen from the above table that the uranyl bands of these three salts in alcohol occupy almost exactly the same positions.

(*f*) *Absorption Spectrum of Uranyl Chloride and Calcium Chloride in Methyl Alcohol.*

In the solution of uranyl chloride in methyl alcohol the *d* and *e* bands are very diffuse, but are entirely separate. By adding calcium chloride a very peculiar phenomenon takes place. The *d* and *e* bands come together and as far as one can tell form a single band. At the same time the *f, g* and *h* bands shift to the red. For a solution containing a .9 normal solution of calcium chloride one finds that the *b* and *c* bands have practically remained in the same position, the *d* and *e* bands have merged into one and the *f, g, h* bands have moved to approximately $\lambda\lambda$ 4260, 4120 and 4010 respectively. The *de* band is approximately at λ 4420.

(*g*) *Absorption Spectrum of Uranyl Chloride in Methyl Alcohol and Water.*

A spectrogram was made of a solution of uranyl chloride of constant concentration in mixtures of methyl alcohol and water. A small addition of water causes a considerable decrease in the absorption power of the uranyl chloride. When the amount of water has reached about 16 per cent. very little further change is produced by further increasing the amount of water. The most important effect of the addition of water is the effect upon the uranyl bands. For a pure alcoholic solution the *a* and *b* bands appear; the *b* band being quite intense. Adding water causes *a* and *b* to both decrease in intensity and apparently to shift towards the violet. A spectrogram of smaller concentration shows the *a, b, c, f, g, h* and *i* bands; the solution containing 8 per cent. water the *b, c, d, e, f, g, h, i* and *j* bands; the 16 per cent. water solution *b, c, d, e, f, g, h, i* and *j*; the 24 per cent. aqueous solution shows all these bands greatly weakened, and in solutions containing a greater amount of water practically only the *b* and *c* bands appear, and these are very diffuse. The general effect upon the positions of the bands is quite remarkable, the *b* and *c* bands apparently being shifted to the violet with increase of water, whereas the ultra-violet bands appear to be shifted towards the red.

(*h*) *Absorption of Uranyl Chloride in Ethyl Alcohol.*

The absorption spectrum of uranyl chloride in the ethyl alcohol shows the uranyl bands quite strongly, although they are less intense than for the methyl alcohol solution. A very interesting resemblance has been found for the various uranyl bands of different mixtures. The absorption spectrum of a solution of uranyl chloride in ethyl alcohol has been found to be almost the same as that of a methyl alcohol solution of uranyl chloride containing a 0.9 normal concentration of calcium chloride or an aqueous solution of uranyl chloride and a 2 normal concentration of aluminium chloride.

The positions of the uranyl bands for the ethyl alcohol solution was approximately:

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
λ	4900	4750	4580	4400	4400	4250	4100	3980	3860

The relation above mentioned comes out much better in comparing the spectrograms. The values of wave-lengths thus far given does not bring this out very well on account of the difficulty of making measurements. Much more work is to be carried on along this line, and the measurements above given are to be considered as more or less of a preliminary character.

(*i*) *The Blue-Violet Band.*

Under the various changes above noted, *i. e.*, of changing the acid radicle, of changing the solvent and of adding foreign substances, the position at which the blue-violet band faded away was approximately λ 4200. This is rather unexpected when we consider the very considerable effects which are produced upon the finer bands.

VII. Absorption Spectrum of Uranous Salts in Solution.

It is quite well known that by reduction the yellow uranyl salts are changed to the intensely green uranous salts. In the present work this reduction was accomplished by adding the same acid to the solution that corresponded to the anion of the salt and then putting in a metal that would produce a colorless salt.

The absorption spectrum of uranous sulphate and uranous

chloride in water was found to be very similar. The absorption of the shorter wave-lengths was complete under the conditions used. The following are the approximate positions of some of the bands: λλ 6700, 6500, 6300, 5480 and 4900. The 6500 band was the strongest one of all, and upon increasing the depth of cell this band widened out so as to unite with the bands λλ 6700 and 6300, forming an absorption band covering hundreds of Ångström units. This is a very characteristic property of many of the uranous bands, that of widening out so as to include a very large portion of the spectrum. The uranyl bands do not change in width very greatly on increasing the depth of cell.

Besides the bands described above uranous chloride shows bands at λλ 4600, 4770 and 4970.

The absorption spectrum of uranous chloride in methyl alcohol was found to differ very much from that of the aqueous solution. The bands at λλ 4600 and 4780 appeared, closely resembling the water bands at the same position. The band λ 4970 in water was broken up into two bands in methyl alcohol at λλ 4930 and 5030. In the alcohol a very broad band appeared at λ 5300, which does not appear at all in the water solution. The band at λ 5580 is very similar to the water band. Weak and broad bands appear at λλ 6150, 6300 and 6480, and a strong band at λ 6750. As the depth of the alcoholic solution is increased the widening of the bands is very different from the widening of the bands of the aqueous solution.

The absorption spectrum of a mixture of calcium chloride and uranyl chloride in water was found to be very similar to that of the pure uranyl water solution. Much further work along the above lines is being carried on.

VIII. An Example of the Complexity of the Problem of Explaining the Origin of Spectral Lines and Bands and the Proposed Method of Attack.

It is a fact that investigations upon the spectral emission and absorption of bodies has been far less fruitful in extending our knowledge of the structure of the atom than had been expected.

This is largely owing to the almost infinite complexity of the structure of the atom and our general ignorance of the forces that exist there. Probably the best known example is that of the uranyl group which we have been describing. Let us consider the spectral vibrations that can be produced by components that exist or may be produced from the apparently simple UO_2 group: (1) We have the absorption spectrum described above. At low temperatures most of these bands break up into much finer bands. (2) The uranyl salts under various methods of excitation emit a phosphorescent spectrum of a large number of rather fine bands throughout the visible region of the spectrum. It is quite possible that this spectrum is intimately connected with that of the absorption spectrum. (3) We have the absorption spectrum of the uranous salts which has been described above. This spectrum has been probably caused by the change of valency of the uranium atom. Uranium is known to form quite a large number of oxides and it is quite possible that for each valency of the uranium we have a characteristic spectrum. (This also is being investigated.) It is also quite probable that at low temperatures those spectra would consist of quite fine bands. (4) We have the spark spectrum and the absorption spectrum of oxygen, and (5) that of ozone, which bears no relation to that of oxygen. (6) There is the exceedingly complex spark spectrum of uranium consisting of thousands of fine lines and also (7) the complex arc spectra. From radioactive experiments it is known that uranium is continually breaking down into ionium. (8) Ionium possesses the properties of a chemical atom and most likely has a spectrum of its own. This would make eight spectra. (9) Ionium breaks down into the radium and radium has a very characteristic spark spectrum, as does also (10) the radium emanation. During the various radioactive transformations several α products are emitted with a velocity almost as great as that of light. It is probable that these particles are moving with very great velocities in the uranium atom under ordinary conditions. (11) The α particles are known to be charged helium atoms and therefore under proper excitation would give the helium spectrum. The radium emanation breaks down into Radium A, B, C, D, E and F. These products behave like chemical elements

and probably have characteristic spectra. (12) The final product is lead, which has a very complex spark and arc spectra. During these transformations several electrons have been thrown off from the various products with enormous velocities. In a very large number of the above spectrum lines the Zeeman effect indicates the presence of negative electrons and charged doublets.

We thus see what an extremely complex system UO_2 must be and it might seem almost hopeless to entangle the mystery of its various spectra. At present we know that the arc and spark spectra problem is very complex and that we have very few methods of producing any changes in it. Practically the only method of changing the frequency of these vibrations is by applying a very powerful magnetic field or great pressure and these changes in the frequency are very small. One very important result, however, has been accomplished by Kayser, Runge, Wood and others. This work consists in separating spectrum lines into various series. A series of lines are those whose intensity and Zeeman effect vary in the same way when the conditions outside the atom are changed. The work of Wood is very important, and shows that spectrum lines are due to different systems of vibrators inside the atom. By using monochromatic light of different wave-lengths he has been able to excite diffirent series of lines which constitute altogether the fluorescent spectrum of the element.

Present theories of the atom usually regard the electrons and other vibrators that are the sources of arc and spark lines as being far within the atom and as affected by external physical conditions only under very special circumstances. Stark believes that these electrons may rotate in circular orbits, the locus of the centers of these orbits being a closed curve, say a circle. This system will be equivalent to a positive or negative charge according to the sense of rotation of these electrons. These electrons we will call ring electrons. Supposing these systems to be positive charges, it will require electrons to neutralize these charges. Several of these neutralizing electrons may be in the outer parts of the atom and under certain conditions might be knocked off from the atom. These easily removable electrons will be called "valency" electrons, and can exist under different conditions of "looseness" of con-

nection with the atom. Most of the neutralizing electrons will probably lie far within the atom. For instance, we would expect that in the uranium atom the charged helium atoms are neutralized by negative electrons.

Our theory is that the finer absorption bands of such salts as neodymium, erbium and uranium are due to vibrations of these neutralizing electrons, and that the forces acting upon these are considerably different from those acting on the ring electrons, which, in many cases, give a normal Zeeman effect. It is probable that these neutralizing electrons play the greatest röle in the optical properties of bodies, such as the properties determining the index of refraction, the extinction coefficient, etc.

Usually the equation of motion of such an electron is given by an equation like the following when a light wave of an electric field $E \cos pt$ is passing by it:

$$m\frac{d^2x}{dt^2} + k\frac{dx}{dt} + n^2x = E \cos pt.$$

where m is the total mass (electromagnetic and material) of the electron, $\kappa \cdot dx/dt$ is the damping or frictional term and n^2x is the quasielastic force. It is an experimental fact as shown by the above work and the work of other investigators, that κ and n^2 are not only functions of the electron and the atom, but that they are also functions of the physical and chemical conditions existing in the neighborhood of the atom.

On the other hand, the effect on κ and n^2 for a ring electron, when external physical and chemical conditions are changed, is very small. It is for this reason, and the probable fact that there are relatively few neutralizing electrons, that we believe that much greater progress can be made in determining some of the properties and constitution of various interatomic systems of atoms and molecules by the study of the absorption spectra of uranium and neodymium than by a study of the arc or spark spectra of the same.

The method of attacking the above problem will be to study the effect on the spectra of a body produced by changing the physical and chemical conditions about the light absorbers or emitters within as wide ranges as possible. Some of the possible changes that

can be made are as follows: Take for instance the uranyl group UO_2. We can find the effect upon the absorption bands produced (1) by diluting the solution, (2) by changing the acid radicle to which the uranyl group is united, (3) by changing the solvent and using mixtures of solvents, (4) by adding other salts (like aluminium chloride), or (5) by adding acids of the same kind, as that of the salt of the uranyl group. The effect of adding foreign salts and acids at the same time and then varying the solvent, or the temperature, can also be tried. In this way a very large number of very interesting things can be tested. In most of these changes lc will be kept constant.

In the above examples the temperature (7), the external pressure (8), the electric field (9) and the magnetic field (10) can be changed between wide limits. The latter effect is a very important one. For example, in aqueous solution neodymium salts give a large number of fine bands, in glycerol there are quite a number of new bands replacing the "water" bands, and in the alcohols there are various "alcohol" bands. At low temperatures these bands become very fine and it is quite possible to detect the Zeeman effect. Now it seems quite probable that a "glycerol" band and an "alcohol" band that seem to replace each other as the solvent is changed are both due to the same vibrator. If the Zeeman effect is the same in both cases it would be a strong argument in favor of the above theory. A case that will soon be described is very important. It was found that certain neodymium lines in a pure water solution did not have their wave-length changed when the temperature was changed from 0° to 90°. If, however, calcium chloride was added, then on raising the temperature the above bands were shifted to the red. A very interesting and important investigation is whether the Zeeman effect on this band would be affected by the presence of bodies like calcium chloride.

To be compared with the above changes are changes in the absorption spectra of the crystals of the salt (11) as affected by water of crystallization, or by the presence of foreign substances, or as affected by the polarization (12) or direction of passage of light through the crystal. The absorption spectra (13) of the anhydrous powder at different temperatures, etc., should be found. The

phosphorescent spectrum (14) should be studied in this connection, especially as affected by the mode of stimulation (X-rays, cathode rays, heating or monochromatic light of different wave-lengths). The temperature, electric or magnetic field could be changed about the phosphorescing body. The effect of change of state (15) should be tried if this is possible, also any possible changes of valency of the atoms (16) composing the body investigated. We shall attack the problem from all of these standpoints.

After correlating the data obtained by the above named investigations it is pretty certain that it will be possible to take each vibrator and trace the effects produced upon it by the above changes. It is also quite certain that we shall also know something of the nature of the vibrating system and the part that it plays in that complex body we call the atom. We shall now describe a few results obtained by changing the concentration and temperature of a solution of the chemical compound whose absorption spectrum we are studying.

IX. The Effect of Rise in Temperature on the Absorption Spectrum of Certain Salts in Aqueous Solution.

(*a*) *Uranous Chloride* (*B, Plate VII.*).

To a normal solution of uranyl chloride in water was added a small amount of hydrochloric acid and zinc. The production of hydrogen reduced the uranyl to the uranous state. The same can be done in some cases by simply passing hydrogen gas through the uranyl solution. The solution was placed in the glass trough and a temperature run made as in the usual manner. The thickness of layer was 1 mm. The length of exposure was 50 sec. to the Nernst glower and 4 mins. to the spark, the current through the glower being 0.8 amperes and the slit width 0.20 mm. Starting with the strip nearest the comparison scale the temperatures were 8°, 17°, 33°, 48°, 62° and 73°. An exposure was also made at 80° which is not shown in the spectrogram *B*.

At 8° a mist formed on the prisms and for this reason the spectrum film taken at this temperature is much underexposed and the bands appear wider than at the higher temperatures. At this tem-

perature there is complete absorption of the shorter wave-lengths to λ 3650. A blue-violet absorption extends between λ 4050 and λ 4450. Following this band are three strong bands of about equal intensity and each almost 100 Ångström units wide. Their wave-lengths are approximately λλ 4590, 4760 and 4970. Following is a band at λ 5500, a wide band from λ 6400 to λ 6630 and a rather narrow band at λ 6740.

The absorption does not change very greatly until a temperature of 60° is reached. Above this temperature the increase in absorption is quite rapid as the temperature rises. At 73° the ultra-violet band has widened to λ 3800, the blue-violet band covers the region from λ 4050 to λ 5000. The bands λλ 4600, 4770 and 4980 at 8° have shifted slightly to the red with rise of temperature.

None of the other bands seem to shift to the red at all and the broadening seems to be quite symmetrical. The band at λ 5500 has become about twice as wide as it was at the lower temperatures and the two red bands have merged into one band running from λ 6350 to λ 6800. Between 73° and 80° the absorption increases very greatly. All short wave-lengths are absorbed up to λ 5050. The band in the green runs from λ 5450 to λ 5600 and the band in the red has also widened very greatly, extending from λ 6200 to λ 6800.

(*b*) *Copper Bromide* (*A and B, Plate VIII.*).

The two spectrograms showing the absorption spectra of copper bromide in water for various temperatures were made for different concentrations of the salt. *A* gives the absorption of a 2.06 normal solution 1 mm. thick and *B* the absorption of a 0.25 normal solution 8 mm. thick. The time of exposure to the Nernst glower was 2 mins. (current 0.8 amperes and slit width 0.20 mm.) and to the spark 6 mins. Starting with the strip nearest the comparison scale the temperatures at which exposures were made for *A* were 6°, 17°, 30°, and 45°; for *B* 6°, 17°, 31°, 46°, 59°, 71°, and 85°.

As the spectrograms show, the effect of change of temperature on the absorption spectrum is very marked. Above 45° the concentrated solution did not transmit enough light to affect the photographic film.

(*c*) *Chromium, Calcium and Aluminium Chlorides* (*A and B, Plate IX.*).

A, Plate IX., represents a spectrogram showing the effect of rise of temperature on an aqueous solution of chromium and aluminium chlorides. The concentration of the chromium chloride was 0.125 normal, and of the aluminium chloride 2.28 normal. The depth of layer was 9 mm. The length of exposure to the Nernst glower was 4 mins. (current 0.8 amperes and slit width .20 mm.) and to the spark 6 mins. Starting with the strip adjacent to the comparison scale the temperatures were 6°, 19°, 36°, 51°, 66° and 81°.

The most marked effect of the aluminium chloride was the production of a very pronounced unsymmetrical broadening, which does not occur when a pure aqueous solution of chromium chloride is heated. At 6° the ultra-violet band extends to λ 3000, at 81° to λ 3300, a much greater widening than takes place for a chromium chloride solution in water. At 6° the blue-violet band extends from λ 4100 to λ 4600 and the yellow band from λ 5800 to λ 6200. Not only do the red sides of the blue-violet and yellow bands widen out enormously towards the red, but the short wave-length edges of these bands actually move towards the red. This effect is much more pronounced in the changes of temperature from 51° to 66° and from 66° to 81°. At 81° the blue-violet band extends from λ 4150 to λ 5050 and the yellow band from λ 5900 throughout the remaining portion of the spectrum, as far as the film is sensitive. The fine chromium bands in the red do not appear.

B, Plate IX., is a spectrogram, giving the absorption spectrum of a .125 normal concentration of chromium choride and a 3.45 normal concentration of calcium chloride in water at different temperatures. The length of the solution was 9 mm., the length of the exposures to the Nernst glower were for 5 min. and to the spark for 6 min. The current through the glower was 0.8 amperes and the slit width 0.20 mm. Starting with the strip adjacent to the comparison scale the temperatures at which the exposures were made were 6°, 19°, 31°, 45°, 64° and 80°.

The effect of rise of temperature upon the absorption spectrum of a mixture of chromium chloride and calcium chloride is very similar to the effect on the mixture of chromium chloride and

aluminium chloride. The blue-violet and the yellow bands widen unsymmetrically and the short wave-length edges of these bands apparently moves towards the red at the higher temperatures.

At 6° the ultra-violet band extends to λ 2800, the blue-violet band from λ 4000 to λ 4400 and the yellow band from λ 5600 to λ 6100. At 64° the ultra-violet band extends to λ 3100, the blue-violet band from λ 4000 to λ 4600 and the yellow band from λ 5650 to λ 6300. At 80° the ultra-violet band extends to λ 3250, the blue-violet band from λ 3950 to λ 5000 and the yellow band from λ 5700 throughout the red end of the spectrum as far as the film is sensitive.

(*d*) *Uranyl Chloride* (*A and B, Plate X.*).

A spectrogram (*A*, Plate X.) was made of the absorption spectrum of a normal aqueous solution of uranyl chloride, the depth of cell being 3 mm. Exposures were made to the Nernst glower for 90 sec., current 0.8 amperes and slit width 0.20 mm. The time of exposure to the spark was 6 min. Starting from the comparison spectrum the temperatures were 6°, 18°, 34°, 52°, 68° and 82°.

At 8° the ultra-violet band extended to λ 3550, the blue-violet band from λ 4000 to λ 4450. The bands *a*, *b* and *c* appeared, but the *a* band is very faint. The wave-lengths of the *b* and *c* bands were λλ 4565 and 4725.

At 82° the ultra-violet band extends to λ 3700, and the blue-violet band from λ 3950 to λ 4600. At this temperature only the *b* band appears,—*a* being very weak and *c* being completely merged into the blue-violet absorption band. The *b* band is located at λ 4755.

A spectrogram, *B*, Plate X., was made of a uranyl chloride water solution 0.0156 normal concentration and a depth of layer of 196 mm. Exposures were made to the Nernst gower for 30 sec., current 0.8 amperes and slit width 0.20 mm. No exposures were made to the spark except for comparison spectra. Starting with the numbered scale the temperatures were 6°, 18°, 29°, 44°, 59°, 71° and 79°.

For this concentration there is a very slight temperature effect. There is a very faint transmission band between the ultra-violet and blue-violet bands. This is extremely faint and is practically un-

affected by temperature. The blue-violet band widened slightly with rise in temperature. The uranyl bands in the concentrated solution were much stronger and wider than in the dilute solution.

(*e*) *Neodymium Salts.*

A spectrogram (*A*, Plate XI.) of the absorption spectrum as affected by change of temperature was made of neodymium chloride solution in water, the concentration being 3.4 normal and the depth of layer 12 mm. The length of exposure was 2 min. to the Nernst glower, current 0.8 amperes; slit width .20 mm. The time of exposure to the spark was 6 min. Starting with the strip nearest the numbered scale the temperatures were 11°, 22°, 33°, 45°, 59°, 73° and 85°.

An absorption band appears at about λ 2970 for the 11° temperature, a very strong band from λ 3250 to λ 3285 and an adjacent band from λ 3285 to λ 3310. At 11° a very narrow and feeble transmission band separates these two bands. At 85° the transmission band has weakened very much. At 11° a very strong band lies between λ 3490 and λ 3580. The band λ 4274 is about 8 Ångström units wide. An extremely narrow band appears at λ 4297, λ 4306 and λ 4324. At λ 4234 is a wider and rather diffuse band, it being about 12 Ångström units wide. Bands at 11° lie between λλ 4415 and 4470, λλ 4580 and 4650, λλ 4665 and 4710, λλ 4740 and 4775, λλ 4815 and 4835, and the very wide bands λλ 5010 and 5300 and λλ 5665 and 5935. Weak bands are located at λ 4645, λ 4800, λ 5320, λ 6235, λ 6255, λ 6280, λ 6305 and λ 6380. Rather diffuse bands appear at λλ 6780 and 6840, at λ 6850 and from λ 6870 to λ 6920.

The effect of rise of temperature from 11° to 85° is quite noticeable, although it is not great. In the ultra-violet there is a slight increase in the general absorption. The band λλ 3285 and 3310 widens slightly. The band λλ 3490–3580 at 11° has widened so that at 85° it extends from λ 3450 to λ 3600. The band at λλ 4415 and 4470 has widened but little. The group of bands from λ 4600 to λ 4800 have also widened but little. The faint diffuse bands λλ 4645 and 4800 have practically disappeared. The bands λλ 5010 and 5300 and λλ 5665 and 5935 at 11° have widened at 85° to

λλ 5010 and 5350 and λλ 5660 and 5985. The widening of the latter band is distinctly unsymmetrical. The existence of the band λ 5320 causes the band λ 5010 to λ 5300 to widen unsymmetrically.

The bands in the region λ 6300 become less sharp as the temperature rises. At 11° there was considerable transmission in the region λ 6850. At 85°, however, this transmission disappears and there is practically complete absorption from λ 6760 to λ 6920. The very sharp bands λλ 4282, 4300, 4310, 4322 and 4343 do not appear to change very much with change in temperature. On the strip taken at 73° these bands appear sharper than on any of the other strips.

A spectrogram (*B*, Plate XI.) showing the effect of rise in temperature was made on a neodymium chloride solution in water of c.17 normal concentration and a depth of layer of 196 mm. The amount of neodymium chloride in the path of the light is approximately the same as in the spectrogram, showing the effect of temperature upon a 3.4 normal concentration and a depth of cell of 12 mm. In this case the temperatures were 5°, 16°, 28°, 42°, 59°, 72° and 82°. Exposures were made to the Nernst glower for 3 mm. current 0.8 amperes and slit width 0.20 mm. Each strip was exposed to the spark for 6 mm. The purpose of making this spectrogram was to find the effect of concentration of a salt upon the changes produced by change in temperature.

A description of the bands at 5° and 82° will be given. Any change between these two temperatures that takes place is a gradual one. Transmission begins at λ 2600. Bands appear between λλ 3250 and 3300 and λλ 3455 and 3575. The band λ 4274 is much sharper and narrower than for the more concentrated solution. The numerous fine bands in the region λ 4300 are very faint. The bands λλ 4420 to 4460, λλ 4600 to 4630, λ 4645, λλ 4680 to 4705, λλ 4745 to 4770 and λ 4820 have rather diffuse edges. Wide bands appear from λ 5020 to λ 5290 and from λ 5685 to λ 5920. Diffuse bands are located at λ 5310, λ 6810 and λ 6900. The group in the region λ 6300 appear, but they are extremely faint.

At 82° the general absorption has increased in the ultra-violet and has reached to about λ 2800. It will be noticed here that the effect of rise in temperature is greater upon this general ultra-violet

absorption in the dilute solution, than it is for the concentrated solution previously described.

The band λλ 3455 to 3575 at 5° has widened slightly, having the limits λλ 3445 and 3580 at 82°, the widening being about 15 Ångström units. This band in the concentrated solution widened 60 Ångström units. Practically no effect of temperature is to be noticed upon the bands from λ 4200 to λ 4900 with rise in temperature. At the higher temperatures the bands are slightly more diffuse, but this change is very small. The band λλ 5020 to 5290 at 5° has widened to λλ 5015 and 5285, about 10 Ångström units. The corresponding widening for the concentrated solution was approximately 50 Ångström units, although it must be noted that in the more concentrated solution this widening was mostly due to the increased absorption of the band λ 5310 at the higher temperatures. The band λ 5685 to λ 5920 at 5° has widened to λλ 5775 and 5930, about 20 Ångström units, compared with a widening of 55 Ångström units for the more concentrated solutions. None of the other bands show any appreciable change with change in temperature.

A spectrogram (*A*, Plate XII.) was made showing the effect of temperature upon the absorption spectrum of a 1.66 normal aqueous solution of neodymium bromide, the depth of layer being 6 mm. An exposure of 4 mm. was made to the Nernst glower, at .8 amperes and a slit width of 0.20 mm. The length of exposure to the spark was 6 mins. The temperatures of exposure, starting with the strip adjacent to the comparison spark, were 4°, 20°, 36°, 50°, 68° and 83°.

At 4° there is complete absorption in the ultra-violet up to λ 2600. A broad absorption band appears at λ 2660 to λ 2800 and from λ 2950 to λ 3060. These absorption bands appear with a more or less general absorption. Bands appear at λλ 3460, 3500 and 3540. The band at 4274 is weak. Weak and diffuse bands occur at λλ 4440, 4630, 4695, 4760, 4825, 5095, 5260, 6810 and 6900. Wider bands are located at λλ 5116 to 5140, λλ 5200 to 5240 and λλ 5710 to 5850.

At 83° the spectrum is almost exactly the same as at 4°. The ultra-violet absorption is complete up to λ 3050. The bands at λ 3500 have increased in width slightly and the band λ 4274 is

slightly broader. The bands that have widened appreciably are $\lambda\lambda$ 5195 to 5260 and $\lambda\lambda$ 5700 to 5880. The change in the absorption is greatest when the temperature is changed from 68° to 83°. Up to 68° there is practically no change in the absorption spectrum at all.

A spectrogram (*B*, Plate XII.) showing the effect of temperature was made, using an aqueous solution of .055 normal concentration of neodymium bromide, the depth of the layer being 197.4 mm. This spectrogram was made to compare with that taken with a 1.66 normal concentration of the same salt and a depth of layer of 6 mm. The exposures to the Nernst glower lasted 90 sec. in this case, current 0.8 amperes and slit width of 0.20 mm. The length of exposure to the spark was 6 mins. Starting with the strip nearest to the comparison scale the temperatures of the solution were 5°, 16°, 29°, 42°, 55°, 68° and 84°.

At 5° there is practically complete transmission of light between λ 3400 and λ 2600, no ultra-violet bands appearing, as was the case for the more concentrated solution. The bands $\lambda\lambda$ 4445, 4693, 4760, 4825 and 5095 were somewhat sharper than they were in the concentrated solutions. The two largest bands extended from λ 5200 to λ 5250 and from λ 5710 to 5850. As in the case of the more concentrated solution, so here, the greatest change in the absorption took place in the change from 68° to 84°. The ultra-violet absorption increased up to λ 2900. The bands at λ 3500 became considerably stronger, but they widened very little. The bands $\lambda\lambda$ 4445, 4693, 4760 and 4825 are somewhat weaker than at 5°. The wide bands remained practically as wide as at 5°, λ 5200 to λ 5250 and λ 5705 to 5870. This indicates a widening of about 25 Ångström units for the latter band. For the more concentrated solution the widening of these two bands was 25 and 40 Ångström units respectively. It is thus seen that in the more concentrated solutions the bands widen more with rise in temperature than they do in the less concentrated solutions. At 42° in the dilute solution there appears a narrow band at λ 6710. This increases in intensity with rise in temperature. This band does not appear at all in the concentrated solution.

A spectrogram (*A*, Plate XIII.) was made of neodymium chloride and calcium chloride in water. Exposures were made for 30 sec.

to the Nernst glower, the current being 0.8 amperes and the slit width 0.20 mm. The length of exposure to the spark was 4 mins. Starting with the strip nearest the numbered scale the temperatures were 6°, 17°, 31°, 49°, 63°, 74° and 82°.

The general effect of the addition of calcium chloride is to make all the bands hazier, and to increase the transmission throughout the region of the band. At 6° there is a slight transmission throughout the ultra-violet portion of the spectrum. As the temperature is raised this general transmission is decreased, and at 82° practically no light passes through the solution of shorter wave-length than λ 2800. Sharp bands occur at λ 3464, λ 3500, λ 3535, λ 4276 and weak diffuse bands at λ 4295, λ 4305, λ 4340, λ 4445, λ 4620, λ 4695, λ 4760, λ 4825, λ 5095, λ 5130, λ 5225, λ 5260, λ 5320, λ 5710, to λ 5860, λ 6245, λ 6810 and λ 6900.

At 82° the bands in the λ 3500 region are slightly more intense than at 6°. Practically all the bands from λ 4200 to λ 5200 have become much weaker at the higher temperature. This is especially true of the band λ 4276, its intensity being less than half what it is at 6°. Most of the bands are shifted to the red with reference to the same bands at 6°. For instance, λ 5095 is shifted 5 Ångström units towards the red. The bands λ 4695, λ 4760 and λ 4825 are all shifted to the red at the higher temperature, and especially λ 4825, the shift in thise case amounting to 5 Ångström units. In the case of these bands the shift is not an apparent one due to unsymmetrical broadening, for in this instance there is no broadening at all.

The band from λ 5710 to λ 5860 at 6° has widened very unsymmetrically and has the limits λ 5710 to λ 5920. The short wave-length side is quite sharp and its position is practically independent of the temperature. The long wave-length edge is quite broad and recedes quite rapidly towards the red as the temperature is raised. The bands in the red λλ 6810 and 6900 grow fainter and fainter with rise in temperature, and have practically disappeared at 82°. The band λ 6245 is very weak at 6° and has disappeared at about 60°.

It will thus be seen that not only does the presence of calcium chloride modify greatly the absorption of neodymium chloride, but that it changes the effects due to temperature very fundamentally. In pure neodymium chloride practically no bands decrease in in-

tensity with rise in temperature, and at present no shift has been detected. When calcium chloride is added to the solution most of the bands decrease in intensity with rise in temperature and several are shifted towards the red at the same time. Several bands disappear. Moreover, the band $\lambda\lambda$ 6800 to 6900, although it widens, this widening is entirely on the red side, whereas for the pure neodymium chloride solution this widening always takes place on both sides of the band.

A spectrogram (*B*, Plate XIII.) was made to show the effect of change in temperature upon a 2.15 normal aqueous solution of neodymium nitrate. The length of layer was 3 mm. The exposures were for 40 sec. to the Nernst glower, current 0.8 amperes, slit width .20 mm. The length of exposure to the spark was 6 mins. Starting with the strip nearest the comparison spark the temperatures were 4°, 17°, 29°, 43°, 58°, 71° and 84°.

The changes in the spectrum due to this change in temperature of 80° was very slight. The NO_3 band extends to about λ 3250 at 4°, and to about λ 3280 at 84°. The bands at λ 3500 became considerably wider and their edges more diffuse at the higher temperatures. At the lower temperatures fine bands appear at $\lambda\lambda$ 5210, 5225 and 5240. At 84° these bands all merge into a single band. The red band extends from λ 5705 to 5860 at 4°. The band at λ 5820 is very faint at the lower temperatures. At 84° it is unrecognizable, At this temperature the red band extends from λ 5700 to λ 5880. The widening of this band for the concentrated solution is somewhat greater than for the dilute solution, but the effect of concentration is very slight. This is to be expected since the effect of temperature itself is so very minute.

A spectrogram (*A*, Plate XIV.) was made of an aqueous solution of neodymium bromide 1.66 normal concentration and 54.6 mm. depth of cell. The exposures were 3 mins. to the Nernst glower and 6 mins. to the spark. The current in the Nernst glower was 0.8 amperes and the slit width 0.20 mm. Starting with the strip nearest the comparison scale the temperatures were 6°, 20°, 33°, 47°, 62°, 73° and 82°.

The effect of rise in temperature upon the absorption spectra of this salt was quite marked; practically all of the bands broaden-

ing and becoming more intense. At 6° the ultra-violet absorption extended to λ 3600. At 82° it had advanced to λ 3800. Very narrow and fine bands appear at λ 4186, λ 4300, λ 4308, 4345, 6240, 6265, 6290, 6305, and much broader bands at λ 6380 and λ 6740. Wide bands occur at from λλ 4390 to 4480, λλ 4550 to 4850, λλ 4990 to 5340, λλ 5650 to 5950 and λλ 6760 to 6930, at 6°. At 82° these bands have the following limits respectively: λλ 4380 to 4500, λλ 4540 to 4910, λλ 4960 to 5370, λλ 5620 to 5990 and λλ 6730 to 6960.

(*f*) *Erbium Chloride.*

A spectrogram (*B*, Plate XIV.) was made to show the effect of rise in temperature upon the absorption spectrum of a solution of erbium chloride. For this purpose a 0.94 normal solution of erbium was used and the depth of layer was 48 mm. The solution probably contained a considerable number of impurities, so that in fact the amount of erbium was quite small. The absorption spectrum was found to change but little with rise in temperature, thus indicating a dilute solution. Exposures were made for 30 sec. to the Nernst glower and 4 mins. to the spark. The current through the glower was 0.8 amperes and the slit width 0.20 mm. Starting with the spectrum nearest the comparison scale the temperatures were 7°, 17°, 29°, 46°, 60°, 70° and 80°.

At 70° the ultra-violet is absorbed to λ 3950. As the temperature is raised the ultra-violet absorption increases, and at 80° it reaches λ 3150. Bands from 20 to 40 Ångström units wide occur at λ 3235, λ 3510, λ 3640 and λ 3785. These bands are slightly wider at 80°, but as for all the other erbium bands this widening is very small. Weak and narrow bands appear at λλ 4165, 4425, 4458, 4500 (strong), 4535, 4540, 4555, 4580, 4685, 4750 (30 Å. u. wide), 4810, 4840, 4855, 4870 (strong and 20 Å. u. wide), and 4920, λ 4920 lies alongside of a fuzzy band extending from λ 4910 to λ 4950.

After these comes a rather wide band which for a shorter length of layer would most likely be broken up into a number of much finer bands. This band extends from λ 5190 to λ 5250. At λ 5217 there runs a narrow sharp line through the fuzzier and wider band. Broad (about 30 Å. u. wide) and very faint bands are located at λ 5630 and λ 5760. For greater concentrations these would prob-

ably show as finer bands. The band at λ 6540 is much more diffuse on the red than on the violet side; this possibly being due to a component that is not separated at this temperature. Other bands are located at $\lambda\lambda$ 5365, 5380, 5425, 5445, 5505, 6410, 6440, 6495 and 6690.

The general effect of rise in temperature here is to cause the lines to become slightly fuzzier and to show more of a "washed out" appearance. No shift due to rise in temperature was noticed.

Throughout all the previous work the wave-lengths were read directly from a scale. This scale was made so as to give the wave-lengths in Ångström units directly. It was found in the measurements that the Seed films did not correspond to the Wratten and Wainwright films, when the same spark spectra on the two kinds of films were placed beside one another. This was probably due to different shrinkage of the two kinds of films on fixing, washing and drying. For this reason the wave-length measurements are not intended to be absolutely correct but only relatively so. All the temperature work was done with Wratten and Wainwright films. The relative measurements of fine bands for any spectrogram are probably correct to within a few Ångström units.

X. Summary.

The absorption spectra of the uranyl salts contain a series of bands in the blue and violet. Twelve of these bands can usually be detected for each salt. Starting from the blue end of the series the bands are designated by the letters *a*, *b*, *c*, etc. These bands are usually diffuse and from 30 to 50 Ångström units wide.

The uranyl bands of uranyl nitrate in water are all farther to the violet than the uranyl bands of any other salt investigated, or of uranyl nitrate in other solvents.

The uranyl absorption bands of crystals of uranyl nitrate agree with the absorption bands of an aqueous solution of the nitrate, with the exception of the *f*, *g*, *h* and *i* bands; these latter being shifted to the red in the crystal.

Dilution within the ranges studied does not affect the position of the uranyl bands. Theoretically, all the uranyl salts in water

should give the bands of the same wave-lengths for very dilute solutions.

The uranyl bands of the nitrate in methyl alcohol are all shifted to the red about 50 Ångström units, with reference to the bands in water. Mixtures of water and methyl alcohol show that we have both sets of bands existing for the same solution, the "water" bands increasing in intensity as the amount of water increases. The water bands are the more persistent. This indicates the existence of a hydrate and an alcoholate of the uranyl group. In ethyl alcohol the *a, b, c* and *d* bands are shifted to the red with reference to the methyl alcohol bands. The other bands appear to have the same positions as the methyl alcohol bands.

The absorption spectrum of the anhydrous salt is very complex and the bands could not be recognized.

The bands of uranyl bromide in water, of uranyl acetate in water and methyl alcohol, and also of the anhydrous salt, are approximately of the same wave-lengths, differing but slightly from the wave-lengths of the uranyl nitrate bands of an aqueous solution.

The bands of uranyl sulphate in water are all shifted towards the red about 50 Ångström units, with reference to the uranyl nitrate bands in water. For both the sulphate and nitrate in water the bands are very much alike. The *i* band is very weak in both cases.

Uranyl chloride bands of an aqueous solution are shifted to the red with reference to the uranyl nitrate bands of an alcoholic solution. The addition of calcium chloride or aluminium chloride is found to produce very marked effects upon the uranyl chloride bands. The addition of sufficient aluminium chloride to a water solution of uranyl chloride, or of calcium chloride to a methyl alcohol solution of uranyl chloride is found to cause the *d* and *e* bands to come together, so as to form a single wide band, and to cause the other uranyl bands to shift so that the whole resulting series of bands is almost identical with the series of bands of an ethyl alcohol solution of uranyl chloride. The effect of adding foreign substances also greatly modifies the intensity of the bands. An example of this difference of action is the effect of adding aluminium chloride to an aqueous solution of uranyl chloride. The

a and *b* bands are affected entirely differently; the *a* band being very much reduced in intensity and made narrower, whereas the *b* band becomes very much stronger and wider.

A new set of fine bands in the green has been discovered in the absorption spectrum of an aqueous solution of uranyl chloride. These only appear for pure water solutions; a small amount of aluminium or calcium chloride causing them to vanish. They do not appear for methyl or ethyl alcohol solutions, and for no other uranyl salt except very faintly for the sulphate.

The absorption spectrum of several uranous salts has been photographed. The spectrum is entirely different from that of the uranyl compounds. The absorption spectra of uranous chloride in methyl alcohol and in water were found to be very different. The absorption spectrum of neodymium chloride in glycerol was found to be entirely different from that of the salt in water. Mixtures of water and glycerol seem to indicate the existence of both sets of bands in the same solution. The "glycerol" bands are more persistent with reference to water bands than "alcohol" bands are. Much more work along this line is contemplated.

Rise in temperature has been found in general to cause an increase in the amount of absorption, and to cause the absorption bands to widen. This widening of the bands may or may not be symmetrical.

Some of the absorption bands of uranous chloride widen very rapidly with rise in temperature. Other bands do not widen so rapidly, and seem to be slightly shifted towards the red.

In solutions containing a single salt, it has invariably been found that the bands widen with rise in temperature, and that this widening is greater, the greater the concentration of the solution.

The uranyl bands of aqueous solutions of the chloride and sulphate of uranyl are shifted towards the red with rise in temperature. The intensity of the uranyl bands does not seem greatly modified by changes in temperature.

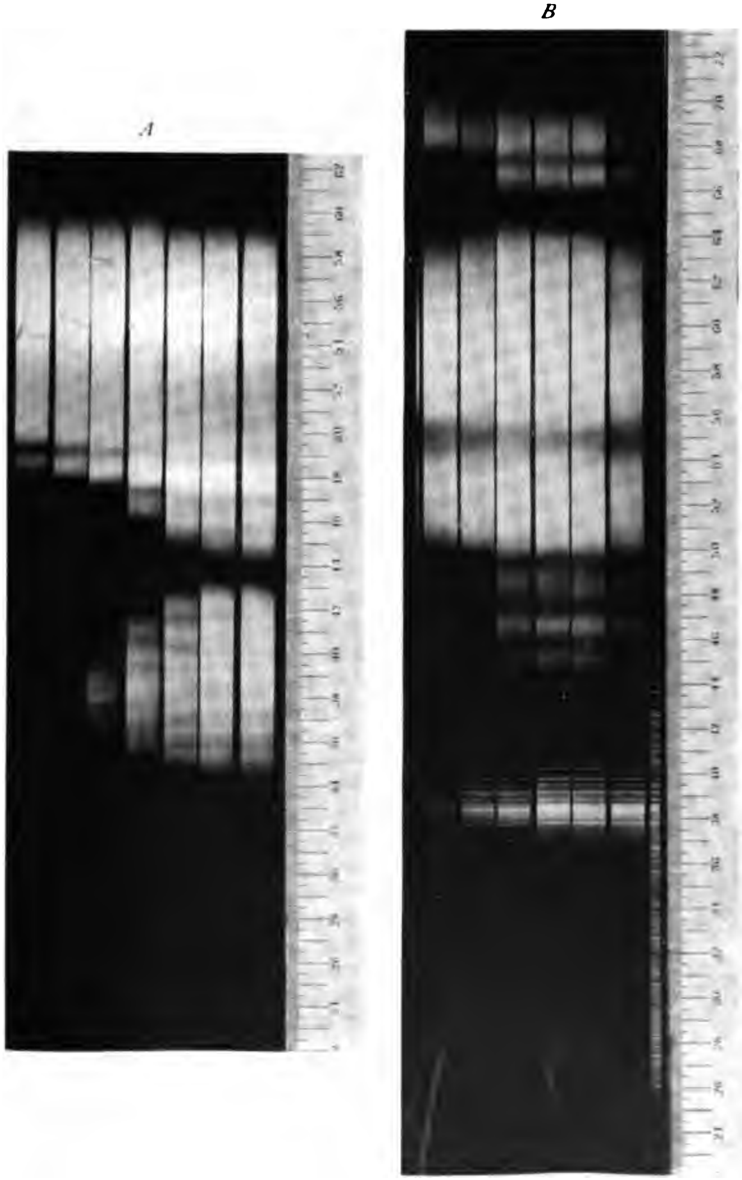
The effect of rise in temperature on the absorption syectrum of a solution of a salt containing calcium or aluminium chloride is very peculiar. The bands usually broaden very unsymmetrically,

and in all cases investigated, the widening has been on the longer wave-length edge. A tyipcal example is shown in Plate III.

Rise in temperature causes the neodymium bands to widen slightly, but no shift of the bands has been noticed. However, when calcium chloride has been added to the neodymium solution, a rise of temperature causes many of the bands to become much less intense, and also causes some of the bands to shift to the red. In the recent work of Becquerel and others it is quite possible that the presence of various foreign bodies in the crystals along with the neodymium may have a very great influence upon the absorption spectrum.

All the above conclusions must be understood to be limited to the conditions and within the ranges described in the earlier parts of this paper.

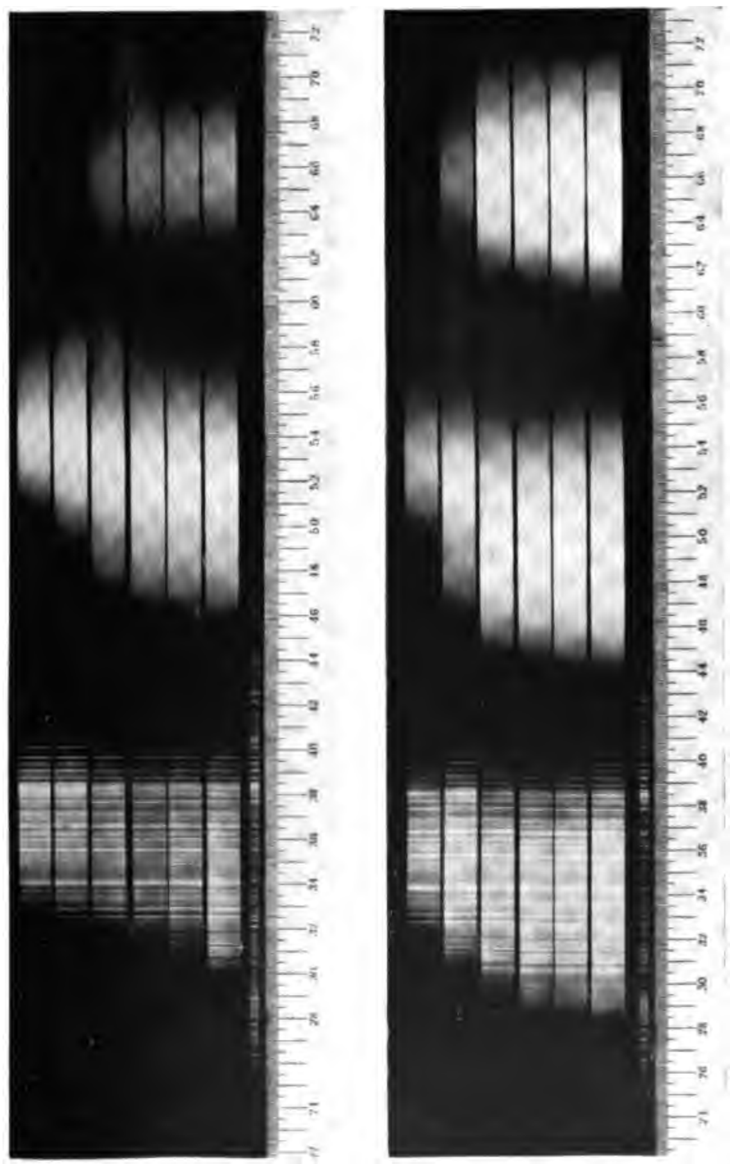
Physical Chemical Laboratory,
Johns Hopkins University,
May, 1909.



A

B

A *B*



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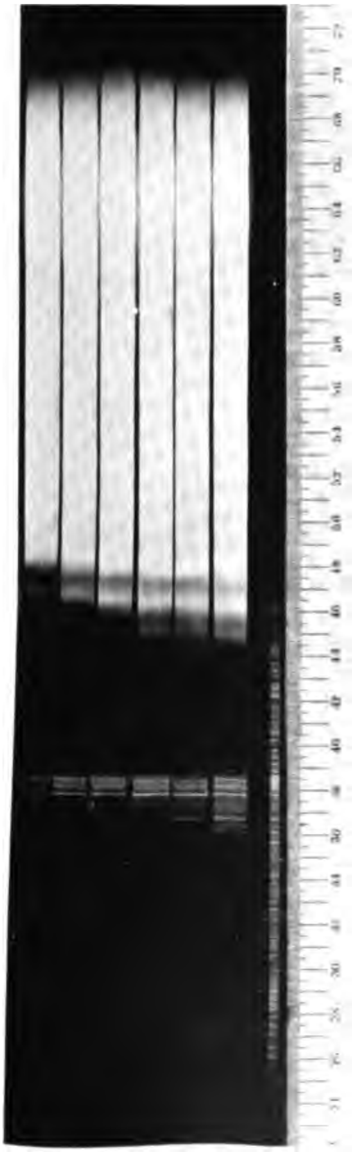

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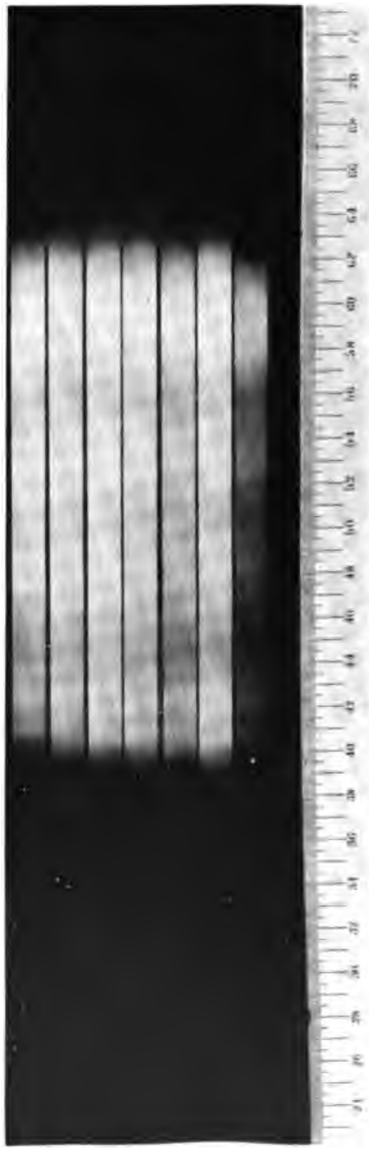

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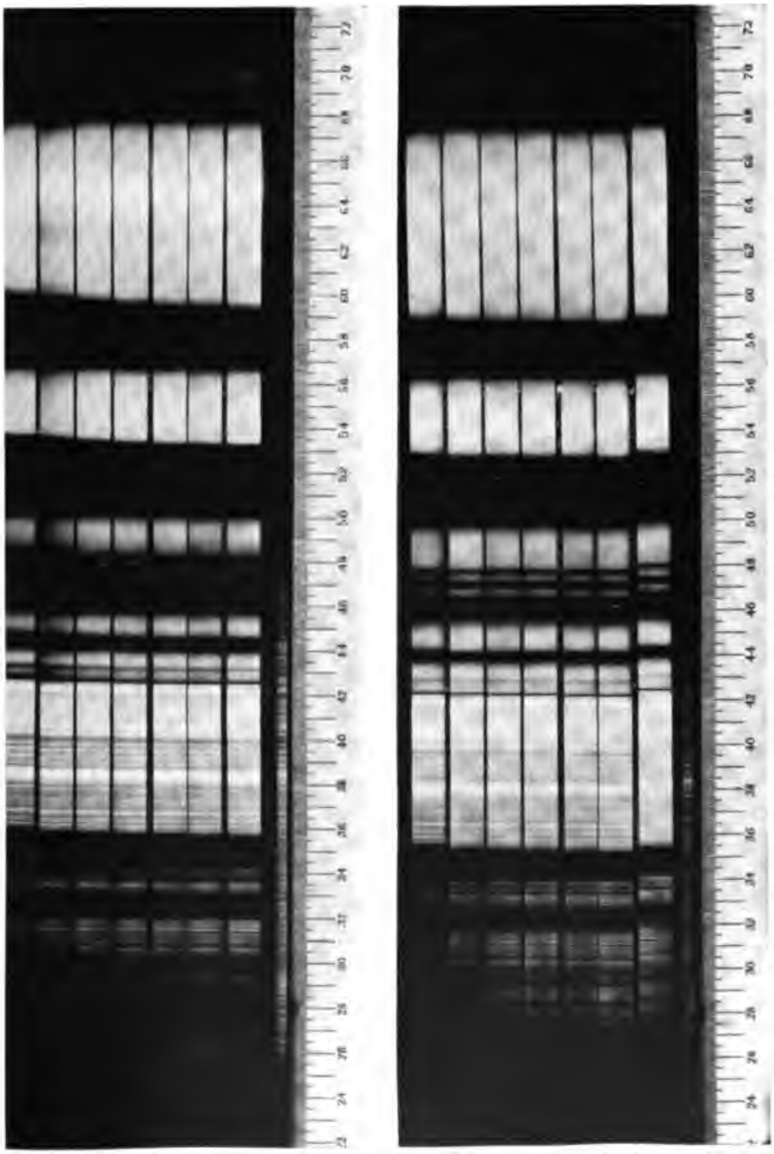

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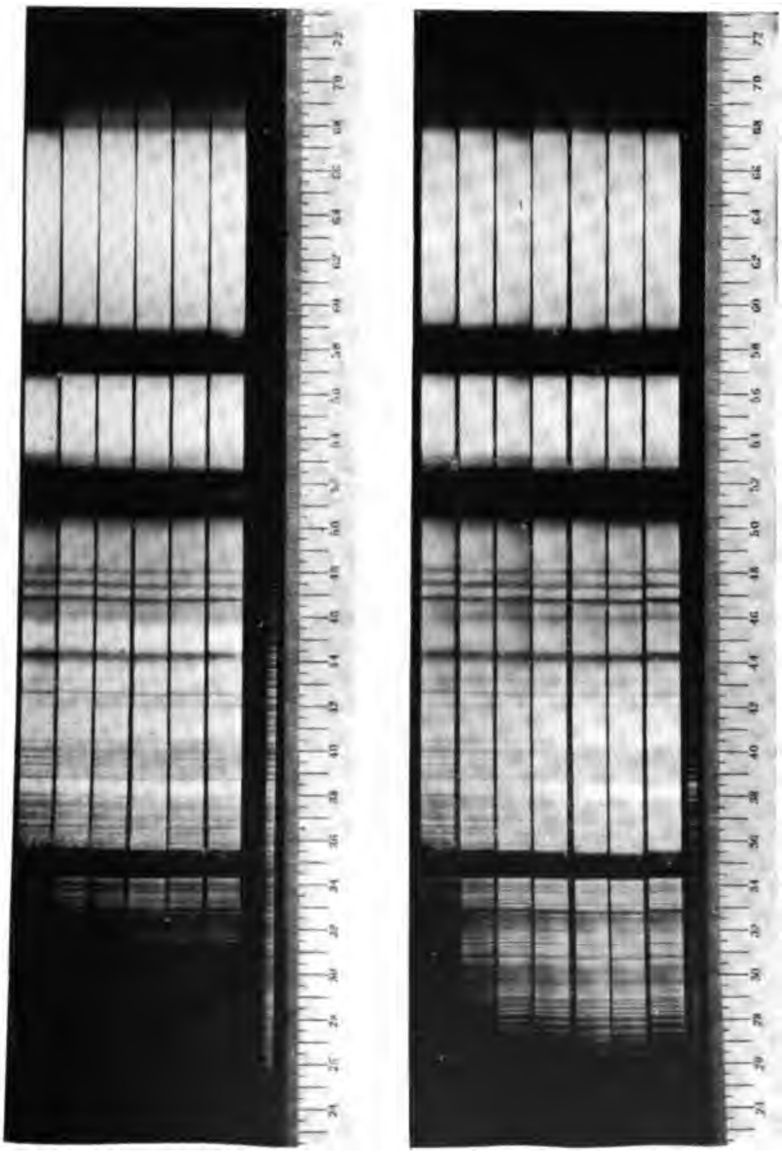

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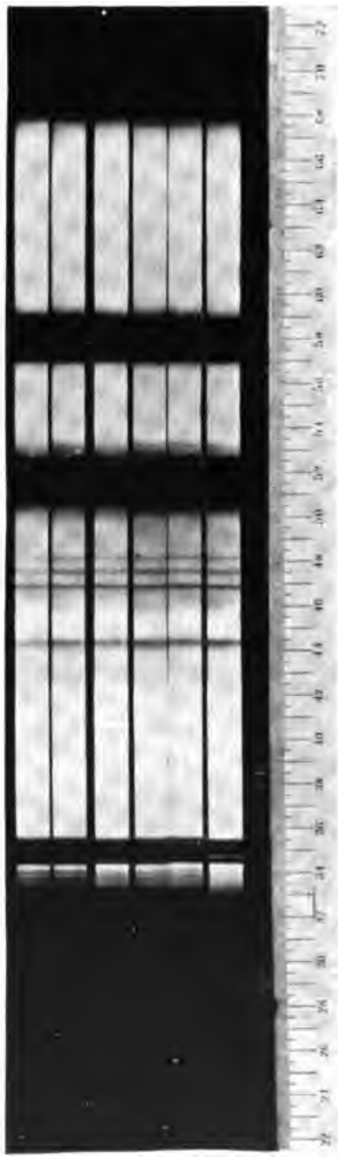

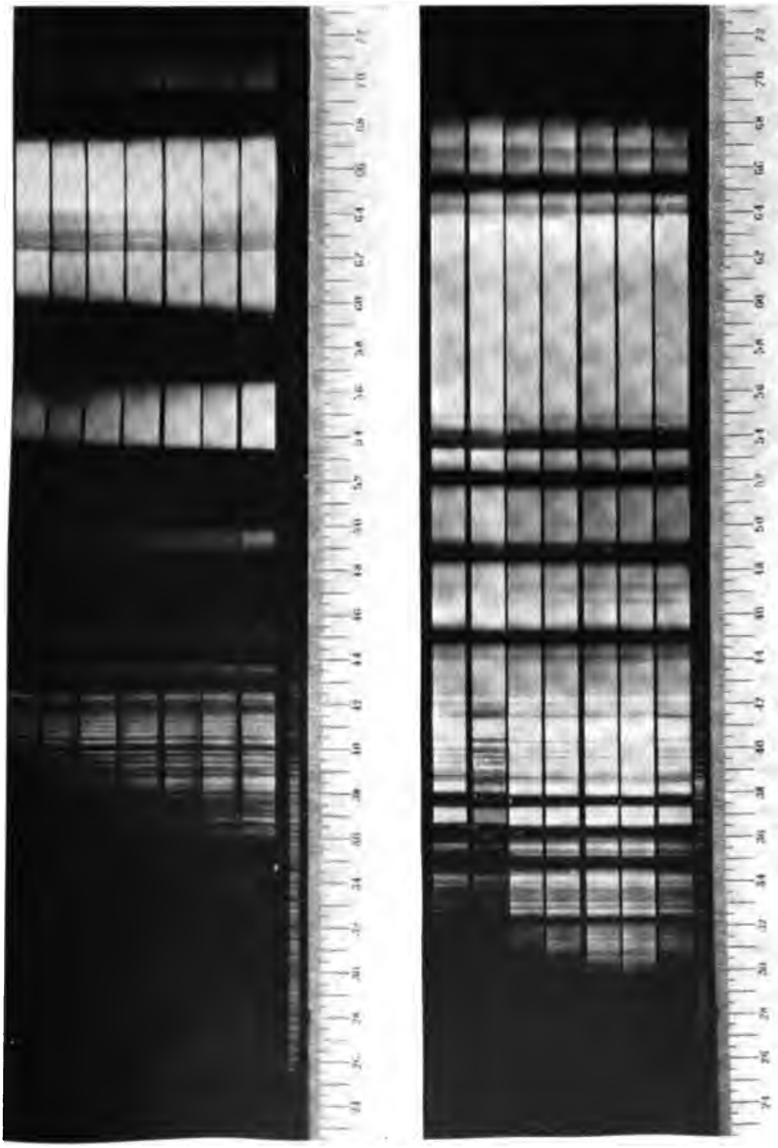

EARTHQUAKES: THEIR CAUSES AND EFFECTS.

By EDMUND OTIS HOVEY.

(Read April 24, 1909.)

The occurrence of three earthquakes in the western hemisphere within the space of nine months in 1906–1907, all of which were attended with disastrous effects upon human life and property, attracted as never before the attention of the world, and particularly of the United States, and focused interest upon the science of seismology in a manner calculated to advance materially the study of movements and other physical changes in the earth's crust. San Francisco, in April, 1906, Valparaiso, in August, 1906, and Kingston, in January 1907, attracted wide notice, but the disaster that overwhelmed Messina, Reggio and vicinity on December 28, 1908, capped the climax, and sufficient reason is apparent for the universal interest now prevailing, one manifestation of which is the present symposium. The thesis of the seismologists is that the chain of earthquake observatories that have been established in the past decade and a half should be extended and united into a network of stations covering the globe, sufficiently, at least, to furnish a complete record of the important vibrations propagated through the earth, indicate their places of origin and provide data for more satisfactory theories as to their causes.

Great earthquakes rank with volcanic eruptions as being the most terrifying of all natural phenomena. Usually coming with no recognized warning, often happening in the night, extremely indefinite as to source, extent and duration, they fill the mind of the human observer with the horror of utter helplessness. They have been far more destructive to human life and property than volcanic eruptions have been, for we have the earthquake shocks of Sicily, 1693, with 60,000 victims; Yeddo, Japan, 1703 (200,000); Peking, 1731 (100,000); Lisbon, 1755 (60,000); Calabria, 1783 (60,000) and Messina-Reggio, 1908 (200,000); besides many others, to

compare with the volcanic outbursts of Krakatoa, 1883, destroying 36,500 victims; Vesuvius, 1663 (18,000); Mt. Pelé, 1902 (29,000) and the Soufrière of St. Vincent, 1902 (1,400), other historic eruptions having entailed comparatively small loss of life.

Although earthquakes have been recorded frequently throughout all historic time, seismology is one of the youngest of the sciences —it is still in its formative state. Scientific interest in the subject has indeed not been lacking, but real edvance was retarded by the fact that, up to the latter part of the nineteenth century, the causes of the phenomena were sought without rather than within the earth itself. Geology was not seriously called upon for aid in solving the problems.

The modern science of seismology is generally held to have had its beginning with the publication, in 1862, of Robert Mallet's great book upon the so-called Neapolitan, or better Basilicata, earthquake of 1857. Mallet, however, approached his task with the preconceived idea that earthquakes were always caused by subterranean explosions, and his observations and deductions were warped accordinigly. The science received its real start from Eduard Suess, when he published in 1874[1] his brilliant generalization showing the intimate association of more than forty Austrian earthquakes with the already well-known Kamp, Thermen and Mürz fault lines near Vienna and postulated crustal movements as an important cause of seismic disturbances, thus combatting the "centrum" theory of Mallet and others. Suess followed this paper with a still more important paper[2] the next year along the same lines showing the intimate relation of the great earthquakes of southern Italy and Sicily to the fault zones of the region. Impetus was added by the publication of the illuminating treatise of Rudolph Hoernes[3] in 1878, in which earthquakes were first definitely classified into (1) those due to the collapse of the roofs of cavities within the earth's crust, (2) those resulting from explosions connected with volcanic eruptions and (3) tectonic quakes, or those caused by crustal movements along fault planes or due to other effects of the action of mountain-

[1] "Die Erdbeben Nieder-Oesterreichs," *Denkschr. k. Akad. Wiss.*, Wien, XXXIII., Abth. I., p. 61, 1874.

[2] "Die Erdbeben des südlichen Italien," *id.*, XXXIV., Abth. I., p. 1, 1875.

[3] *Jahrbuch d. k. k. Geol. Reichsanstalt*, XXVIII., p. 387, Wien, 1878.

building forces. Many others in Europe, Japan and America have contributed to the advance of seismology, but particular mention should be made of the services of Professor John Milne, of England, whose long residence in Japan and intimate study of the earthquake phenomena of that and other uneasy regions have enabled him to contribute more than any other one person to the advance of the new science.

The perfecting of instruments for the purpose of recording movements of every kind in the surface of the earth has vastly extended our knowledge of the character of earth vibrations and enhanced the value of deductions affecting the theory of earthquakes. The instrumental study of earthquakes by means of seismographs, however, can hardly be said to antedate the year 1892, but within the past decade and a half the number of fully equipped earthquake stations has vastly increased, the growth having been considerably accelerated through the interest aroused by the disasters of the last three years. There are now in Great Britain and her colonies fifty seismographic stations equipped with the same type of instrument, while in all the world there are more than two hundred stations equipped with instruments capable of recording world-shaking earthquakes. More than half of these stations are in Europe.

No large part of the surface of the globe seems to be entirely stable, but certain regions or zones are much more liable than others to the occurrence of earthquakes. If we study a map of the world upon which their location has been plotted, we find in the eastern hemisphere a broad belt of seismic activity extending from west to east through the Mediterranean Sea, Persia, the southern Himalayas and the Sumatra-Java group of islands. A branch zone stretches from the southern end of the Caspian Sea northeastward half way across Asia. This is de Montessus de Ballore's "Alps-Caucasus-Himalayas" belt and it has furnished more than 53 per cent. of recorded shocks.[4] A seismic belt practically encircles the Pacific Ocean, the principal points in it being the Japanese Archipelago, Alaska, California, Southern Mexico and Central America and the

[4] F. de Montessus de Ballore, "Les tremblements de terre," p. 24, Paris, 1906.

northern and southern Andes. This "Circum-Pacific" or "Andes-Japan-Malay" belt has given 41 per cent. of the quakes. In the western hemisphere in addition to a part of the circum-Pacific belt, there are the West India Islands and the mountains of Venezuela forming a seismic zone. Earthquakes mostly of volcanic origin have visited many of the islands of the South Seas. The major portions of Africa and South America remain blank upon such a map, probably because little is known about their seismicity.

We are in the habit of thinking of eastern North America as a region free from earthquake shocks. The impression, however, is erroneous, since New England has experienced about 250 recorded shocks since the Pilgrims landed at Plymouth, and there have been at least four great earthquakes in the eastern half of the continent within the past two and one half centuries, one on the fifth of February, 1663, which affected the St. Lawrence Valley over an area more than six hundred miles long and three hundred miles wide as described in the "Jesuit Relations."[5] In 1811–1812 heavy quakes occurred in the central part of the Mississippi Valley, accompanied with considerable subsidence fifty miles south of the junction of the Ohio and Mississippi Rivers. Strong shocks continued for more than a year and evidence of the sinking still persists in lakes and submerged trees. The southeastern part of the United States was the center of an earthquake shock January 4, 1843, the waves of which were felt at points at least eight hundred miles apart.[6] In 1886 occurred the Charleston earthquake, an event still fresh in the minds of most of our population.

As to earthquakes of the several classes, the falling in of the roof of a buried cavity causes slight shocks. Quakes of this kind have often been reported from certain parts of Switzerland, the Tyrol and elsewhere, but all have been local in character. It seems certain too that the blocks falling in the caverns of southern Indiana and Kentucky produced vibrations sensible on the surface, but reports of such have not come under my eye.

Earthquakes arising from volcanic explosions or associated with eruptions form a much more important subdivision. Until within

[5] W. H. Hobbs, "Earthquakes," p. 315, New York, 1908.

[6] H. D. Rogers, *Am. Jour. Sci.*, I., XLV., 342, 1843.

thirty-five years, indeed, it was the general belief that volcanic earthquakes were by far the most numerous and destructive of all. This idea controlled and vitiated Mallet's work, but it is now known to be erroneous, for although it is true that earthquake zones coincide in part with belts of volcanic activity, shocks are more frequent and more severe in non-volcanic regions. The severest quakes of South America have not happened around the great volcanoes; the shocks of California are evidently independent of the now extinct or at any rate dormant volcanoes of the Cascade Range; the recent (1899) great earthquakes of Alaska were in the vicinity of Yakutat Bay, at a long distance from the active vents of the Aleutian Islands or any recent volcanicity; the earthquakes of Japan are most numerous and severe in the non-volcanic parts of the islands; the great disasters of the Caribbean Sea have occurred in Jamaica and at Caracas, hundreds of miles from Mt. Pelé and St. Vincent's Soufrière, and have not been contemporaneous with any eruptions.

On the other hand, some of the most violent of historic volcanic eruptions have been unattended by severe earthquakes or have given rise to shocks of merely local significance. The Island of Martinique in the French West Indies lies within a markedly seismic zone, but the great eruptive activity of 1902–1903 was free from earthquake shocks. This fact is of particular interest, because the eruptions were of the most highly explosive character. Although, however, no vibrations were felt upon the island of Martinique and no subterranean noises were heard there, dull sounds like the booming of distant cannon were heard the morning of the great eruption of May 8, 1902, at Caracas, Venezuela, 450 miles distant, southwest, where people feared that a naval battle was in progress off their coast. Similar booming was reported from St. Kitts, 200 miles northwest of Martinique and from other regions. I myself was on the island of St. Vincent, 100 miles due south of Pelé when the great eruption of June 6, 1902, occurred, and I felt several dull thuds, as if some heavy object had fallen in a neighboring room. The noises seemed to come from beneath the ground, and they were due, in all probability, to subterranean explosions or to the rushing of lava into underground cavities, somewhat on the priniciple perhaps of the water hammer. On the island of St. Vincent

some observers, indeed, had noted an increase of seismic shocks for a year or more before the volcano burst into violent eruption in May, 1902. The eruption itself, however, was free from earthquakes, except apparently for the quivering of the mountain due to the uprush of steam and ejecta through the conduit, just as happens in the chimney of a fire engine under full blast. The chattering vibrations thus set up in the volcano shook a narrow strip of recent beach formation from the west base of the mountain, where the declivity of the shore is considerable.

Vesuvius being the volcano that has been most continually and thoroughly under observation throughout its known history, we naturally look to its records for light upon the relation between volcanic eruptions and earthquakes. When this old center, which was not known to the ancients as a volcano, renewed its activity in the year 79, the first phase was a series of earth shocks which increased in frequency and severity until the afternoon of August 24, when the eruption actually began. The ground is said to have rocked to and fro like the sea, but we read of no great damage as resulting therefrom even in Pompeii and Herculaneum at the very base of the mountain. The outbreak of 1631 occurred after centuries of repose and was heralded by a half year of earthquakes and terrific noises in the interior of the mountain. This history has been repeated again and again in greater or less degree, particularly when the eruptions have been of the explosive kind. According to the report of A. Lacroix, violent earth movements shook the cone of Vesuvius during the great eruption of April, 1906, and were felt throughout much of the surrounding region. Whatever effects have been produced have been local in extent and comparatively light in degree.

The eruptions of Etna usually have been accompanied by the formation of great fissures in the upper part of the cone, and the opening of these fissures has been accompanied by severe vibrations of the surface of the mountain, as has been vividly portrayed by Silvestri in his account of the eruption of 1879, but the shocks seldom affect the mainland of Calabria across the narrow Strait of Messina. Stromboli, the "Lighthouse of the Mediterranean,"

often shakes its island, but the disturbances are rarely felt in nearby Sicily.

The most violent of all recorded volcanic explosions is that which took place in the Strait of Sunda, August 26–27, 1883, when the volcano of Krakatoa was blown to pieces. This outburst destroyed half the mountain and left soundings of 160 fathoms where part of the cone had formerly stood. It produced sea waves that affected tide gauges half way around the world; air waves that traveled three times around the globe before they ceased to be distinguishable; and it threw dust into the air to such a height that it remained suspended for months, but the earthquake shocks produced were strictly local in character and were scarcely felt at Batavia, 90 miles from the crater.

Another of the great explosions of modern times was that of July 15, 1888, when the Japanese volcano Bandai-san, extinct for a thousand years, burst into sudden eruption. In the immediate vicinity of the mountain a moderately severe earthquake shock lasting about twenty seconds was felt at half past seven in the morning. This was soon followed by additional shocks which culminated when the explosion occurred at the surface, but none was felt severely beyond a limited area.

Even the eruptions of the Hawaiian volcanoes, Kilauea and Mauna Loa, which are the types of the class of "quiet volcanoes," have sometimes been accompanied by severe local earthquakes. Many eruptions of Mauna Loa, indeed, have been recorded of which the first indication to the inhabitants of the town of Hilo only a few miles away has been the light seen at night reflected in the clouds from the streams of flowing lava. On March 27, 1868, however, there began a series of earthquakes on the southern flanks of the mountain which increased in frequency and intensity for a week and culminated in one of the most severe eruptions known in the history of the volcano, during which a great fissure opened, discharging vast quantities of lava that flowed to the sea.

In the words of Dr. Titus Coan,[7] who was on the island at the time:

[7] *Am. Jour. Sci.*, II., XLVI., 107, July, 1868.

Meanwhile the whole island trembled and shook. Day and night the throbbing and quaking were nearly continuous. No one attempted to count the sudden jars and prolonged throes, so rapid was their succession. And even during the intervals between the quakes, the ground and all objects upon it seemed to quiver like the surface of a boiling pot. The quaking was most fearful in Kau. . . . The shocks and quiverings cintinued with different degrees of intensity until Thursday, the second inst. [April] . . . when, at 4 P. M., a shock occurred which was absolutely terrific. All over Kau and Hilo the earth was rent in a thousand places, opening cracks and fissures from an inch to many feet in width, throwing over stone-walls, prostrating trees, breaking down banks and precipices, demolishing nearly all stone churches and dwellings, and filling the people with consternation. This shock lasted about three minutes.

Mr. F. S. Lyman[8] writes as follows of his experiences at Kau during this disturbance:

First the earth swayed to and fro from north to south, then from east to west, then round and round, up and down, and finally in every imaginable direction, for several minutes, everything crashing around and the trees thrashing as if torn by a hurricane, and there was a sound as of a mighty rushing wind. It was impossible to stand; we had to sit on the ground, bracing with hands and feet to keep from being rolled over. . . . The villages on the shore were swept away by the great wave that rushed upon the land immediately after the earthquake.

Some observers estimated that more than 2,000 shocks occurred during this period of disturbance. In spite of the violence of this earthquake on Mauna Loa, it was quite local in extent. No damage was done in the northern half of Hawaii even by the heavy shock of April 2. This shock was felt distinctly on the island of Maui, 110 miles distant, for 90 seconds, shaking furniture, pictures and walls and causing small sea waves. At Oahu, 210 miles from the centrum, the shocks were slight, and though they occurred in the middle of the afternoon, most of the inhabitants of Honolulu were not aware that an earthquake had occurred.

From the human standpoint, the most disastrous of the earthquakes assigned to volcanic causes is that which occurred at Casamicciola on the Island of Ischia, July 28, 1883. When it took place there was a large assemblage of people in the theater, which was of stone and collapsed under the shock, killing most of the audience. Only one house in the whole town was left standing and it is estimated that about 1,900 people lost their lives in the disaster. In

[8] *Am. Jour. Sci.*, II., XLVI., 110, July, 1868.

Naples, however, only twenty-two miles away, the shock was felt by but few people, and the seismographs in the observatory on Mt. Vesuvius did not record it at all, though the instruments at Rome and Florence showed the passage of some extremely light vibrations. The depth of the focus has been calculated at about a half mile and Casamicciola received the vertical shock. The latest eruption of Mte. Epomeo, Ischia's great volcano, occurred in 1302.

Many other instances of volcanic earthquakes might be cited, but perhaps none within historic times have been more severe than those which have been mentioned. All show extremely restricted areas of disturbance, a fact which indicates a comparatively slight depth for the origin of the shocks and a far smaller expenditure of total energy than is developed in connection with the great tectonic quakes. It must not be overlooked, however, that some earthquakes, the origin of which is doubtful, may rightly be assigned to a volcanic origin. Furthermore, the intrusion during past geologic time of countless dikes, sills and laccoliths of igneous rock, the occurrence of which is known from exposures all over the world, must have been accompanied by sudden dislocations, causing earthquakes. Such quakes would be of combined volcanic and tectonic origin. It cannot be asserted positively that they are not occurring at the present epoch.

This brings me now to the consideration of the third and most important class of volcanoes, viz., tectonic quakes, or those which are caused by dislocations in the earth's rock crust due to the action of mountain-building forces. Mountain regions of high geological antiquity, like the Appalachian protaxis and the Scandinavian Peninsula, have had time to adjust themselves to the crustal strains due to their elevation and hence are rarely the scene of great earthquake shocks. In the younger mountain systems, however, such as the Apennines, the Japanese archipelago, Central America and those of California, where young strata abut unconformably against old, the adjustment to strains is still going forward, the cumulative effect being followed by sudden and irregular release of pressure, producing the vibrations which we know as earthquakes. Some of these tectonic quakes have sensibly affected enormous areas. That of Lisbon, 1755, was felt from northern Africa on the south to

Scandinavia on the north and to the east coast of North America on the west, an area estimated by Baron von Humboldt at four times that of the whole of Europe. The Andean earthquake of 1868 shook severely a strip of country 2,000 miles long. The modern seismographs have given pronounced records of earthquakes whose origin was certainly not less than 8,000 miles distant—truly world-shaking events.

The depth of the origin of the shocks below the surface of the earth probably never exceeds thirty geographical miles and usually is not more than from five to fifteen miles. The geological structure of the region through which the earth waves are propagated affects the rate of advance of the same earthquake in different directions and produces many changes in the direction of movement and great differences in the destruction wrought upon buildings. Heavy earthquake shocks are transmitted through the earth at a greater velocity than light ones and the same shock shows different rates in different materials.

In the case of distant quakes three disturbances are recorded instrumentally. The first set of waves to arrive comes on a direct course through the earth's mass; the second set comes along the shortest route on the surface, while the third set arrives by the opposite and longest surface route. The last are comparatively feeble, and they may arrive three and one half hours behind the second set. The first set of waves, those coming through the earth, are propagated with the greatest velocity, which is practically uniform and is about ten kilometers (6¼ miles) per second. These direct waves have been shown by Marvin to be longitudinal in character, and this character combined with their velocity is supposed to cause them to give out the musical sounds which are the premonitory rumblings of an earthquake. The second set are the surface waves due to the "principal portion" of the earthquake, and the increased use of delicate instruments of measurement has led to the acceptance of 3.3 km. per second as their normal rate of propagation. The determination of these various velocities leads to the conclusion that the crust of the earth is practically uniform in constitution to a depth of at least thirty miles.

The duration of an earthquake and the number of shocks in it

vary indefinitely. The Charleston, San Francisco, Kingston and many other quakes lasted only from thirty to forty seconds. Milne states that the average duration of 250 earthquakes of moderate intensity recorded by instruments in Tokyo between 1885 and 1891 was 118 seconds. The first shocks are almost always succeeded by after shocks which may continue for weeks, months or even years.

It has not been possible yet to determine the periodicity of shocks or to predict with any degree of accuracy the time of the occurrence of an earthquake. Some earthquake regions are subject to frequent shocks, while others experience them only at long intervals. The frequency of earthquakes, considering those of all amplitudes, is not generally realized. The globe, indeed, may be said hardly ever to be free from seismic disturbances of some kind somewhere, since the average of all recorded shocks, according to de Montessus de Ballore, is more than fifteen per day, and there are between fifty and sixty heavy shocks per year. The bare enumeration by this author of those occurring in 1903 alone fills a book of six hundred tabulated pages, and he has compiled the data and plotted the position of 159,781 earthquakes that have been recorded up to the end of 1903.

At the same time that important quakes are the result of tectonic movements in the earth's crust, they may themselves be the causes of more or less important changes in the surface of the earth. Sharp waves passing through mountain regions have been known to produce land slides, shatter rocks, displace larger or smaller segments of cliffs, open fissures in the soil or cause subsidence in alluvial regions. Springs, brooks, rivers and lakes have been formed, altered or obliterated as a result of earthquake action. Great earthquakes have usually produced important sea waves causing much destruction along the coast and, sometimes, permanent changes due to erosion and transportation of material.

Several scales for the purpose of indicating the severity of an earthquake shock have been proposed. The one most commonly employed is known as the Rossi-Forel scale, which distinguishes ten degrees of intensity according to the effects produced upon human observers and structures. Another widely used scale is that which has been devised by Professor G. Mercalli. This likewise

consists of ten degrees of intensity and depends upon human observers and the effects upon buildings for the classification of a shock.

On account of the vagueness of these series, the influence of the personal equation of the observer in placing shocks in accordance with them and the over-importance attached by them to effects upon human property, other scales have been proposed, the best of which are based upon instrumental records. Difficulties in using the latter, however, arise through the small number of instruments actually at work, and the Rossi-Forel and Mercalli scales are still found very useful, particularly in the collection of data.

I shall close what I have to say regarding the subject of the afternoon by brief descriptions with illustrations of the earthquakes that occurred at Charleston, S. C., in 1886, at San Francisco in 1906, at Kingston, Jamaica, in 1907, and at Messina in 1908.

The Charleston Earthquake.

The most important earthquake occurring in the eastern part of North America during the historic period was that which devastated Charleston, South Carolina, in 1886. This was investigated under the auspices of the United States Geological Survey by Major Clarence E. Dutton and his assistants, their report being published in the Ninth Annual Report of the survey.

About eight o'clock in the morning of August 27, 1886, the villagers of Summerville, 22 miles northwest of Charleston, S. C., were startled by the noise and shock of what was at first thought to be a heavy blast or a boiler explosion. The sound seemed very near, but no cause for it was learned that day. Around five o'clock the next morning the noise and shock came again and more heavily, and the idea that an earthquake had occurred became general and was strengthened by light tremors that were felt that day and the next. The affair seemed then to be over, for nothing unusual was heard or felt on the thirtieth and during daylight of the thirty-first. The noises or shocks were felt by very few people in the city of Charleston, but they were the premonitions of the great earthquake

that began at 9:15 P. M. of the thirty-first. In the words of Dr. G. E. Manigault, a resident of Charleston, as quoted by Dutton:[9]

Although the shocks at Summerville excited uneasiness in Charleston, no one was prepared for what followed. . . . As the hour of 9:50 was reached there was suddenly heard a rushing, roaring sound compared by some to a train of cars at no great distance, by others again to an escape of steam from a boiler. It was followed immediately by a thumping and beating of the earth underneath the houses, which rocked and swayed to and fro. Furniture was violently moved and dashed to the floor, pictures were swung from the walls and in some cases completely turned with their backs to the front, and every movable thing was thrown into extraordinary convulsions. The greatest intensity of the shock is considered to have been during the first half, and it was probably then, during the period of the greatest sway, that so many chimneys were broken off at the junction with the roof. The number was afterwards counted and found to be almost 14,000.

Apparently there were two maxima, the first of ten seconds duration, the second of six, with an interval of comparative quiet of 22 to 24 seconds. The whole period to be assigned to this destructive double shock is about 68 seconds.

Another observer states that four severe shocks occurred before midnight and that three others followed at about 2, 4 and 8:30 o'clock A. M.[10] Afterquakes occurred for months. Twenty-seven persons were killed outright and at least 56 more died from injuries received and exposure suffered. The money value of the property destroyed was estimated for Charleston alone at between $5,000,000 and $6,000,000. Not a building wholly escaped injury. Damage to buildings was greater on the low made ground than on the natural higher parts of the city.

The occurrence of visible surface waves was so definitely asserted by so many observers and with such detail of description that the fact of their formation cannot be discredited. The passing of such waves has often been included in the description of earthquakes, but their actual existence had been doubted, on account of the difficulty of explaining their origin. The amplitude of the surface waves in some parts of Charleston is estimated by Dutton at nearly or quite a foot and the average amplitude for the city at three or four inches.

[9] Ninth Annl. Rept. U. S. Geol. Survey, p. 231. Washington, 1889.
[10] *Op. cit.*, p. 217.

Besides throwing down walls and chimneys and moving houses bodily on their foundations, the earthquake caused wooden posts and brick piers to sink vertically into the earth; compressed railroad tracks into more or less complicated curves or stretched them apart; opened innumerable fissures in the ground, and formed hundreds or craterlets at many places out of which gushed water, sand and mud in copious streams.

The earthquake waves traversing Charleston were localized as coming from the northwest and from the west. The principal epicentrum was determined as being about sixteen miles northwest of the city and one mile from the little railway station at Woodstock, and a secondary epicentrum about fourteen miles due west of town. The focus of disturbance was a line or plane estimated as being twelve miles below the surface "with a probable error of less than two miles." The velocity of the wave motion throughout the eastern half of the United States was calculated as averaging 190 miles per minute. The intensity reached No. 2 of the Rossi-Forel scale as far away as New Orleans, Clinton, Mo., La Crosse, Wis., Saginaw, Mich., Burlington, Vt., and Boston—an extreme radius of about 1,000 miles. The Charleston earthquake is classed as a tectonic quake, though no evidence of faulting was apparent on the surface.

(Lantern slides were shown depicting the destruction of buildings in Charleston and vicinity and the formation of fissures and craterlets.)

The San Francisco Earthquake.

California has always been known as a seismic region. Professor E. S. Holden has catalogued 514 shocks, 254 of which affected the region of San Francisco alone, within the period between 1850 and 1886. During the nineteenth century there were ten severe quakes; that of 1868, known as the Mare Island quake, having such a disastrous effect upon the city of San Francisco that serious doubts were entertained of the advisability of rebuilding on the same site, but these fears were soon forgotten and the city rapidly rose again. It was rebuilt, however, without much reference to the lessons that might have been learned from the experience.

In the Sierra Nevada, forming the eastern half of the state, earthquakes are likewise frequent. In 1872 occurred the great Owens Valley quake, which was one of the most severe on record and was the result of movements producing a series of faults along a line more than 100 miles long with a throw of from ten to twenty feet. This mountain system is formed of Precambrian granites, gneisses and schists, upon which have been laid down upon the west an unconformable series of late Paleozoic and Mesozoic strata. The coast ranges, in which the earthquakes occur with far greater frequency, are composed of a granitic core against which rest extensive Mesozoic and Cenozoic strata upon which are thick marine Pleistocene and recent beds. The latter are full of the fossil shells of still living species of mollusks and show that elevation is still going forward in California.

The San Francisco Peninsula is traversed by at least five known lines or zones along which movement, or faulting, has occurred again and again. The principal of these zones is the San Andreas, which takes its name from an important lake through which it runs. It is likewise known as the Stevens Creek fault, as the Portolá-Tomales fault or more simply as "the rift." This zone continues northwest in a slightly curved line to Point Arena and southeast to the mountains west of Hollister. This is the continuous extent of the fault, some 190 miles, but it probably extends under the ocean beyond Cape Mendocino to the north and into the mountains southeast of the line recently disastrously affected.[11] According to H. W. Fairbanks[12] the recognized rift extends from Shelter Cove, Humboldt County, as far southeastward as the Colorado desert and is 700 miles long. Dr. Fairbanks states further that the great Tejon earthquake of 1857 was caused by movement in the same fault zone.

The recurrence of horizontal and vertical movement along the northern 200 miles of this fault line caused the earthquake which at

[11] "The California Earthquake of 1906," by David Starr Jordan and others. G. K. Gilbert, map, p. 317. San Francisco, 1907.

[12] "The California Earthquake of 1906," pp. 321–337. See also "Report of the California State Earthquake Investigation Commission," by A. C. Lawson, chairman, p. 48. Washington, 1908.

5:12 o'clock A. M., western time, April 18, 1906, wrought ruin or serious damage over a belt 50 miles wide and 300 miles long. The approximate position of the epifocal point of the disturbance is given by F. Omori as being in latitude 38° 15′ N. and longitude 123° W., near Tomales Bay.[13] The horizontal shearing movement varied from nine to twenty feet toward the N.N.W. or the S.S.E.; the vertical movement did not exceed two feet at any locality and usually was absent, upthrow where present being on the west side of the rift. Among the effects along the line of the fault were rifting and bulging of the soil, offsetting of fences, roads and walks, splitting and overturning of trees, landslides in the mountains, wrecking of railway tunnels, spreading and telescoping of lines of waterpipe. This is the most disastrous earthquake that has visited the United States, though the chief destruction wrought was due to the fire that followed in the train of the quake rather than to the shock itself. About four hundred people are known to have lost their lives in the catastrophe, and at least $350,000,000 worth of buildings and other property were ruined by the shock or consumed by the flames. An exact statement of the pecuniary loss caused by the shock cannot be made, but the insurance companies finally agreed upon a settlement to the effect that one-fourth of the damage was due to the earthquake and three-fourths to the fire, and this estimate may be accepted as the best that can be made. More than four square miles of the city of 400,000 inhabitants was devastated.

The main part of San Francisco lies about eight miles northeast of the fault line, and the propagation of the waves through the city was in a direction N. 76° E., nearly normal to the fault line. In general the advance of the wave motion on each side of the rift was away from it. Omori concludes that both sides of the fault line were displaced toward the N.N.W., the west side more than the east, the amount of apparent slip being merely differential. In San Francisco the chief damage was wrought upon structures built upon alluvial or made ground. High steel-frame structures which were not stiffly braced acted like inverted pendulums, causing ruin to their walls. This was illustrated in the case of the City Hall in San Francisco and the library buildings at Stanford University

[13] "The California Earthquake of 1906," p. 289.

and the City Hall at Santa Rosa. The main source of the earthquake is thought to have been situated at a considerable depth below the surface (Omori).

(Lantern slides were shown to illustrate the destruction of buildings in San Francisco, Santa Rosa and Leland Stanford Jr. University, and the geologic and topographic changes wrought in the surface of the ground along the line of fracture.)

The Kingston Earthquake.

The Blue Mountains, rising 7,400 feet above the level of a sea 18,000 feet deep, form the back-bone of the island of Jamaica. They trend northwest-southeast and, according to Robert T. Hill,[14] from the earliest axis of folding now apparent. Upon this have been super-imposed later east-west flexures corresponding with the crustal movements that early in the Mesozoic era determined the chief characteristics of the Greater Antilles. Charles W. Brown,[15] reports observing "transverse faults in the Blue Mountain region which undoubtedly indicate lines along which fractures may occur." Professor Hill assumes an east-west axis of folding with an anticline producing the trend of the Greater Antilles and leaving a parallel syncline coinciding with the Bartlett Deep just north of Jamaica.

Such strong relief coupled with folding indicates a high state of tension in the earth's crust. Resistance to stress is diminished on steep slopes, especially when the application of pressure to the ends of an axis is not made in the same plane, giving rise to torsional strains. Fracturing results, tending to follow old fault planes, and these fault planes were originally determined by zones of weakness in the rocks. Fracturing, as we have seen, produces earthquakes. Montessus de Ballore acquiesces in the folding postulated by Hill and embraces the Greater Antilles, including Jamaica, within the great Alpine geosynclinal. The region experiences frequent shocks and one of the most dreadful disasters of modern times occurred within it in the year 1692, when, as a result of an earthquake, the greater part of Port Royal, the capital of Jamaica, sank into the

[14] *Bull. Mus. Comp. Zoöl.*, Vol. XXXIV., p. 164.

[15] *Popular Science Monthly*, Vol. LXX., p. 385, May, 1907.

sea. The city was built upon a narrow sand spit formed of the detritus brought down by rivers from the mountains of the interior or cast up by the sea. It is estimated that 2,000 people lost their lives in this disaster, when a tract of land about a thousand acres in extent sank so as to lie thirty or forty feet under water.

After the destruction of Port Royal the city of Kingston was established on the gradually rising Liguanea plain across the harbor from the old capital, and it flourished for 215 years, becoming a compact city of 60,000 inhabitants. Its business portion extended along the water front and was only twelve blocks long and two wide. The city was built, however, upon unconsolidated gravels and sands —alluvial and coast deposits that gave a foundation but little more secure than the sand spit gave to old Port Royal. Hence when the earthquake of January 14, 1907, occurred, 85 per cent. of the buildings in the city was injured or destroyed, and fire completed the ruin over ten or fifteen blocks of the business and warehouse section.

The shock probably began at 3:33 P. M., though an exact statement cannot be made through lack of accurate standard time in the island. This defect as to time has made it impracticable to plot any coseismal lines. The first series of vibrations, the great shock, lasted 35 seconds, more or less, but the duration varied with the position of the observer. The longest period was reported from the north shore and as being 90 seconds. After the preliminary tremors, which were heard before they were felt, the shock was double, the first maximum being reached in about ten seconds, followed by a second and less acute climax before the vibrations ceased. The interval between the preliminary tremors and the main shock was almost insensible. After shocks occurred for several months. Through the city of Kingston and its immediate vicinity the earthwave shown by the first climax passed from west to east, but three miles north of town the direction of motion was distinctly from the south, while in the Hope River valley five miles east of the city, the advance was from the northwest. The earthwave recorded by the second maximum of shock was more undulatory in character than the first and seems to have originated more to the south of the city. This direction of motion combined with the first produced a twisting counter-clock-wise movement of slender upright structures

like statues, columns and chimneys and had a noticeable effect on buildings.

According to Professor Brown:

The dip of the angling cracks at Kingston points to a locus of disturbance much to the west of that city, while the lines of isoseismals indicate the intensity area to be in the eastern half of Kingston. . . . The only conclusion then is that the eastern end of the Liguanea plain was the nearest area to the real epicenter that by nature of material would give the greatest amplitude to the destructive epifocal waves. Further, the angle of emergence at Kingston coördinated with the proximity of a probable epicenter together with the limited area of disturbance indicates a shallow origin of about three miles.

As is demanded by theory and observed in fact the vibrations increase in violence on passing from an elastic to an inelastic medium—the destruction wrought in Messina, San Francisco and other places has been worse in the sections built upon alluvial or other loose soil than in those built upon rock, and Kingston was entirely upon such loose material. The experiences of these and other regions show that the destructiveness of an earthquake is not necessarily greatest in the epifocal area. If the locus of disturbance is in or under an elastic rock-mass and the shock is propagated into a region of inelastic loose material, the destruction in the latter may exceed that in the real epicenter. The fault which was the locus of the San Francisco quake is some miles from the city.

The shock of the Kingston earthquake was not sensible on the island of Haiti to the east or on Grand Cayman to the west, but Santiago de Cuba, 120 miles to the north, felt it slightly. This indicates an ellipse as being the generalized form of curve for the isoseismals, with the longer axis extending approximately north and south. At Annotta and Buff Bays on the north shore of Jamaica, opposite Kingston, the destruction wrought was almost as severe as at the capital city. The inference is that renewed faulting along north-south fault lines caused the earthquake.

The building construction of Kingston was as bad as the foundation upon which the city rested. Brick structures predominated, but for the most part it was evident that the brick had been laid dry in poor mortar. Such buildings collapsed under the shock. Those that were properly put together withstood the quake better. Wooden houses with good braces and well fastened together were not thrown

down. Massive walls showed cracks from half an inch to two inches wide. The double amplitude of the wave motion of the earth is estimated at not more than one inch. Such an amplitude is small when compared with the four-inch amplitude calculated by Omori[16] for the earthwave of the San Francisco (1906) quake, the 6 to 12-inch amplitude estimated by F. A. Perret[17] for the earthwave at Messina in last December's quake, or the one foot maximum amplitude given by C. E. Dutton[18] for the Charleston earthquake wave. These largest estimates were derived from effects in soft ground and are probably excessive.

From a geological standpoint the movements causing the Kingston earthquake were less important than the changes in the earth's surface that were produced by it. Surface evidence of the former has not yet been discovered, but the latter are quite apparent. Beginning in the city water front, a belt of fissuring and subsidence skirted the eastern half of the harbor and returned along the inner (northern) base of the Palisadoes. Opposite the city the zone of disturbance forked, one branch maintaining the original direction and passing through Port Royal, while the other curved northwestward touching Ft. Augusta and dying out in the River Cobre valley, eight to ten miles northwest of town.

From soundings taken for Professor Brown, it was learned that "in several places along the edge of the harbor the bottom had sunk from old soundings of a fathom and a half to over six fathoms, and that on the harbor side of the base of the Palisadoes a series of step faults reached a maximum depression at the shore to the north of four fathoms." Port Royal sank from 8 to 25 feet. The zone of disturbance was from 100 to 300 yards wide, containing where exposed many fissures and craterlets out of which water, sand and mud gushed to heights of three or four feet. The fissuring was caused by the compression and expansion of the earth due to the passage of the earthquake wave, but the cause of the subsidence is not clear, for the harbor as a whole did not sink—only an encircling belt. Perhaps solution of the soft limestone where

[16] "The California Earthquake of 1906," p. 307, 1907.

[17] *Am. Jour. Sci.*, IV., XXVII., 327, April, 1909.

[18] Ninth Annual Rept. U. S. G. S., p. 269. Washington, 1889.

the ground waters enter the harbor left caverns into which the overlying material was shaken by the quake (Brown). No sea wave of importance accompanied or followed the shock.

(A series of lantern slides was used to show the destruction caused in the city, the sinking of Port Royal point and the faulting, fissuring and formation of craterlets along the Palisadoes.)

THE MESSINA-REGGIO EARTHQUAKE.

Time after time during the historic period Italy has suffered from the effects of serious earthquakes, but never before so severely as from that which occurred in Calabria and Sicily on December 28, 1908, when 200,000 human beings are supposed to have lost their lives. The cities of Messina in Sicily and Reggio in Calabria were completely wrecked, and many other villages and towns were laid in ruins or damaged throughout an irregularly elliptical district 85 miles long by 50 miles wide, extending from Pizzo, Calabria, on the northeast to Riposto, Sicily, at the sea base of Mt. Etna, on the southwest. The epifocal area was the Strait of Messina, with the epicentrum at or near the northern end of the Strait. More precisely, the longer axis of the ellipse of greatest destruction (from Ali to Palmi, about 35 miles), as shown by isoseismals, lies in the strait and runs N.N.E.-S.S.W.

Calabria and northeastern Sicily form a district of extreme seismicity that has been visited by several disastrous earthquakes, among which those of 1783, 1785 and 1905 stand out with prominence on account of their destructiveness to human life and property. Volcanic quakes have been associated with eruptions of Mt. Etna, but they have been strictly local in effect, and their influence has not been seriously felt across the Strait. All the severe shocks have originated in Calabria or under the Strait of Messina are of tectonic character, the geological structure being particularly favorable to the production of such quakes. Forming the backbone of Calabria and extending beyond Messina in Sicily there is an elongated area of Archean gneisses and mica schists. Along this axis there occur nearly horizontal beds of Miocene age up to an altitude of 3,300 feet above the sea, while along the Strait of

Messina there runs a fault with thousands of feet of throw, the uplift being upon the Calabrian side of the Strait. Movement appears to be still going on along this and other fault zones, resulting in repeated earthquakes. Furthermore, the slopes into the submarine depths on both sides of the "toe" of Italy are very steep and therefore unstable.

Toward the end of 1908 the seismic activity of the region was evidently on the increase, and noteworthy shocks were felt November 5 and December 10, while F. A. Perret[19] reports that at 5:20 A. M., December 27, just twenty-four hours before the occurrence of the great shock, the seismograph at the Messina observatory registered an important earth movement. The observatory was wrecked by the great earthquake, but the instruments had been installed in its cellar and Dr. E. Oddone[20] of the seismographic service found them intact and the records intelligible, when he reached the place January 1. These records showed that the quake began at 5:21:15 o'clock A. M., December 28, with a gentle movement the force of which increased during ten seconds and then diminished during ten seconds. After two minutes of calm came the great shock, lasting 30 to 35 seconds, which was recorded by seismographs all over the world. This was followed by comparatively light shocks at 5:45, 5:53 and 9:05 o'clock A. M. of the same day, and by noteworthy quakes at 2:51 and 7:30 o'clock P. M. of the following day. For several days and even weeks minor shocks continued to occur. Some of these "after-shocks" were strong enough to add to the damage caused by the principal quake. According to Mr. Perret[21] the intensity within the megaseismic area was between the ninth and tenth degree of the Mercalli scale decreasing rapidly with increasing distance from the epicentrum, and the centrum was not deeply located, being possibly fifteen kilometers ($9\frac{3}{8}$ miles) beneath the surface.

Messina was a beautiful city stretching for miles along the shore of a magnificent harbor. Lying in an advantageous position on the short cut from the Eastern Mediterranean to the Tyrrhene

[19] *Am. Jour. Sci.*, IV., XXVII., p. 321, April, 1909.
[20] *La Nature*, XXXVII., 103, January 16, 1909.
[21] *Loc. cit.*, p. 321.

Sea, the city has enjoyed prosperity for centuries, in spite of frequent visitation from earthquakes. The city was almost completely destroyed by a shock in February, 1783, but the people seem to have learned nothing from their experience with an unstable land. The Messina of yesterday—the city does not exist to-day—was constructed of stone and rubble and old cement. The buildings lined narrow streets and were three, four and even five stories high with massive walls. Hence when the shock came and raised and then dropped the ground for half a minute, the houses, stores, hotels, churches and government buildings were shaken into unrecognizable heaps of débris, filling the sites of the structures and obliterating the streets. The sea-wall in front of the city was partly destroyed, and the promenade along the harbor sank in places below the water.

Reggio di Calabria likewise has suffered frequently from earthquakes, but until within the past few years the inhabitants had not profited by experience to put up earthquake-proof buildings, and all the old houses in the city were demolished by this latest quake. New houses not more than ten meters (33 feet) high are said to have resisted the shocks perfectly. Throughout the Calabrian earthquake district the buildings erected since the disaster of 1905, according to the specifications of the Milan Committee, are reported to be intact in spite of the severe shaking thus received, but all these are low structures.

Photographs show that there was some fissuring of the ground at Messina, and it is reported that "vast chasms" were opened at both Messina and Reggio, but the latter statement is probably incorrect. Professor G. B. Rizzo is quoted as stating[22] that the sea bottom rose in some places, for he saw several boats out of water at the places where they had been anchored some distance from the original shore. The extensive breaking of telegraphic cables indicates submarine disturbance, but the fact of any considerable change in the configuration of the sea bottom remains to be proven and can only be established by careful soundings. No changes in the coast line have occurred, as far as can be detected without an

[22] *Nature*, Vol. LXXIX., p. 289, January 7, 1909.

instrumental survey. It is stated positively that the ground sank in several places in Messina, Reggio and elsewhere, particularly along the harbor front in Messina and along the sea front and in the center of Reggio; but all the low-lying parts of the two cities were built upon unconsolidated alluvial and shore material, permitting, as in the earthquakes of San Francisco and Kingston, severe and destructive oscillations and displacements.

As is usual with shocks occurring along or near the seacoast, the earthquake was accompanied by a "tidal wave," the sea retreating for a considerable distance and then returning into the strait with growing force. The wave was not at all violent in the deep water of the strait and was of importance only as it came into the shallower water near shore, where it was eight or ten feet high. Its crest swept across the marina, or esplanade, bordering the harbor at Messina two or three minutes after the great earthquake shock occurred, and some comparatively slight damage is assigned to the water. The wave was somewhat higher at Reggio than at Messina and attained its maximum on the coast south of Taormina (Perret). In Reggio the buildings on the low land along the coast were flooded. The wave injured a few boats at Syracuse near the southeastern corner of Sicily; but it was scarcely perceptible at the Island of Malta, about 165 miles south by east of Messina, where it arrived at 7:15 o'clock A. M. The sea gauge at Ischia, about 190 miles north-northwest of Messina registered maximum oscillations of 22 centimeters (8.6 inches) at 2:30 o'clock P. M. and at 8 o'clock P. M. If the former was due to the quake that destroyed Messina and Reggio at 5:25 o'clock that morning the rate of advance northward was much less than it was southward.

(A series of slides was shown illustrating the effects of the earthquake in Messina, Reggio di Calabria and Scylla.)

THE EVOLUTION AND THE OUTLOOK OF SEISMIC GEOLOGY.

(PLATES XV AND XVI.)

BY WILLIAM HERBERT HOBBS.

(*Read April 24, 1909.*)

CONTENTS.

PART I: THE EVOLUTION OF SEISMIC GEOLOGY.

Introduction.—Speaking generally, the present condition of a science is so largely the consequence of an evolution by slow stages, that if the past be reviewed the present stands revealed. Zoölogy, which began with the encyclopædists as a descriptive science, passed into the comparative stage with the advent of Cuvier, and entered

upon its fruitful genetic period when the modern view-point was given it by Darwin. Looking back upon this evolution, we note that the order is in every way a natural one. The facts of observation should first of all be assembled; they must next be compared with a view to establishing correspondences, and, finally, the explanation of the correspondences must be sought in genetic relationships.

Of geology it may be said, that the natural order of its evolution was exactly reversed; for the genesis of the earth and the full order of events in its history had supposedly been given to man through divine revelation. The growth of the science began, therefore, only after a measure of emancipation from the tyrrany of religious dogma had been achieved.

The Natural Development of Seismology Prevented by False Theory.—It may well be doubted if there is another branch of science which has been so long held in fetters by false theory as the branch of geology which treats of earthquakes. Had fate been more kind, it might have been the earliest to develop; for the seats of ancient culture were in earthquake countries, and it will hardly be claimed that the phenomena of earthquakings are not such as to attract the attention. Theories of cause do, indeed, date back before the beginning of the Christian era, the dominating one being that of Aristotle which connected the quakings with explosive sources of energy, conceiving that gases confined in subterranean cavities brought on quakings in their struggles to escape. For the times, this theory seemed to be well supported by facts, since earthquakes were generally manifested at the time of great volcanic eruptions, and volcanoes and earthquakes were common to the same countries. The Aristotelian theory of earthquakes acquired prestige from the adhesion to it of Strabo and Pliny among the ancient philosophers, and at the opening of the nineteenth century, through its adoption by von Humboldt and von Buch, who then dominated the field of geological thought.

The middle of the nineteenth century is a turning point in the history of nearly all sciences toward a greater exactness of observation. Academic discussions in large measure gave place to careful and painstaking observation or to laboratory experimentation. Yet almost at the moment when Darwin and Huxley were

opening a new world to students of biology, the way to progress in seismology was effectually closed through the commanding authority of a pseudo-scientific work of great compass, written by the English physicist, Mallet. Darwin's great theory was an induction reached on the basis of extended observations and of meditations with an open mind; Mallet, on the other hand, approached his work firmly intrenched in a preconceived notion which the facts were assiduously, though perhaps unconsciously, twisted to confirm.

Assuming that Mallet's method had been a sound one, his elaborate observations conclusively proved the fallacy of his theory; for instead of pointing to a definite centrum, his results ranged with noteworthy uniformity between depths of 10,000 and 45,000 feet. The history of science furnishes no more striking example of a great monograph wrought out with laborious scientific method and yet absolutely lacking in scientific spirit or judgment, for with a naïve simplicity Mallet drew from his results the conclusion that, "the probable vertical depth of the focal cavity itself does not exceed three geographical miles, or 18,225 feet, at the outside." Nowhere in the two bulky volumes of his report is the possibility of a non-existence of the centrum even raised.

As was true of the famous fallacy of Werner concerning the origin of basalt, it was here the commanding position of the author which gave his theory its authority; and, although the impracticability of his method soon came to be generally recognized, the fundamental idea was destined to survive at least half a century as the standard doctrine of seismology. It was the brilliant system of Huyghens for treating the propagation of wave motion carried over bodily to seismology, which caused it to be so warmly welcomed by physicists and elasticians, to whose care this branch of science was thereafter entrusted. As late as 1899, the depth of the imaginary origin of a particular earthquake was sought by no less than four different methods with results which ranged from 21 kilometers on the one hand to 161 upon the other, these results apparently not shaking the worker's faith in the reality of the earthquake focus.

It becomes ever more clear that men of science discover in the main those facts only which their working hypotheses indicate to be important. For this reason a theory which is largely correct, grows

by elimination of the false and augmentation of the true, whereas a theory essentially false yields nothing, and by discouraging effort bars the way to progress. With the aid of mathematics and by an abundance of exact observation, the more or less occult Aristotelian theory was by Mallet clothed in a modern dress and thus made respectable in the company of the modernized sister sciences. The cause of the earthquake disturbance was by the very nature of the theory hidden so deep beneath the earth's surface as to be removed from direct observation, and was, therefore, a matter suitable only for speculation.

At the opening of the twentieth century, almost fifty years after Mallet had modernized the theory of Aristotle, authors of text-books of geology quite generally disposed of the subject of earthquakes by a treatment of the outlines of the Mallet theory in the compass of a few pages. How generally the investigation of earthquakes was excluded from the field of research in geology is strikingly shown by the activities of the United States Geological Survey, a bureau employing the largest staff of working geologists of any in the world and including in its field subjects as diverse as paleontology and mineral resources. In the years 1868, 1872, 1886 and 1887 earthquakes of the first magnitude wrought damage to property within the national domain, and with one exception no effort was made by the national bureau to investigate these phenomena, and but little by independent geologists. Since the intellectual shock from the California earthquake of 1906, individual geologists have begun to take advantage of this opportunity for study, even though the golden opportunity had already passed.

The Process of Averaging in Mapping Isoseismals and Coseismals.—Aside from its occult and speculative basis, which removes it from the reach of direct observational studies, the centrum theory has yet assumed to adopt the observational method of modern science. The isoseismal and coseismal lines which belong to the Mallet conception of an earthquake centrum must be obtained through averaging the results of observation either of the intensity of the shocks or of the time of their arrival. In how far it has been necessary to "adjust" data in order to make the circular or elliptical curves concentric about the epicenter and represent uniformly de-

creasing values as they recede from it, one who has not compared the individual data will scarcely believe. A local intensity which is too large can be explained either by a soft or a wet basement, by an earthquake "bridge" or by probable error of observation; while one too small may be explained by an earthquake "shadow," by an interference of waves, etc. Many curiously anomalous data not possible of explanation on any of these grounds may be dismissed as "earthquake freaks."

As regards time of arrival of shocks, "too early" or "too late" data have not uncommonly been included among those which seemed *a priori* the most reliable. Especially good examples of such data are furnished by the studies of the Agram earthquake of 1880, the Andalusian earthquake of 1885, the Charleston earthquake of 1886, and the Indian earthquake of 1887. Out of 260 time data collected by Dutton in connection with the Charleston earthquake, 47 were rejected as "too early."

To average the determinations of an unvarying value in order to eliminate the errors of observation and experiment, is indication of a desire to secure accuracy which must be commended as eminently scientific in its nature; but to average the values of a property the distribution of which either in space or in time is likely to be significant, is, on the contrary, one of the most pernicious, as it is one of the most common and unconscious methods. Such a practice is often condoned on the ground that the data may otherwise appear to possess an accuracy beyond what they really have; forgetting, what is far more important, that through the averaging process the data lose their most significant characters. Now that so many sciences are entering upon their quantitative stages it is important that this method be corrected.

A companion fallacy to the supposed necessity for averaging data of different values is that nature in all its moods has avoided angles and straight elements in favor of the curving outline, and that in consequence results are incorrect in proportion as they bring out strong accent, or definiteness of character, or exhibit straightness of contour. In no field, perhaps, has this fault been more often committed than in topographic mapping, where it has been encouraged as tending toward accuracy. A new era is dawning, however,

and the wonderfully improved maps which have been brought out in recent years by the United States Geological Survey and by European surveys have been secured through the elimination of the process of averaging and "rounding off" of angles. Significant character is thus taking the place of a lack of expression in the older maps.

In a similar way the isoseismals and coseismals, which have assumed to represent the distribution in space and in time of the seismic activity of a district, have through averaging of results removed all true expression of seismic distribution. It is likely, however, that this method will yet, at least for a number of years, effectually retard the natural progress of seismology.

The Evolution of the Fault Block Theory of Earthquakes.—It would be incorrect to state that no progress was made in seismic geology during the last half of the nineteenth century, but it would be only the truth to say that such progress as there was, was achieved in spite of and almost in defiance of the orthodox doctrine of seismology. Nine out of ten reports upon special earthquakes made during that period have included only the maps of isoseismal and coseismal lines, to which has been added a computation of the depth of the supposed origin.

It is now proposed to trace the development of the tectonic conception of earthquakes as it has grown into the fault-block theory of the present day. To the Austrian school of geologists and to its leader, Eduard Suess, must be credited the pioneer work upon the geology of earthquakes. The discovery of the localization of heavy shocks along definite lines, or the recurrence of epicenters (surface loci of heavy shocks) along such lines, has been a characteristic of the Austrian method, which dates from a paper published by Suess in 1872. Such lines in the surface, generally approximating either to a right or to a broken line, were in some cases identified with the traces of fault planes and in others were shown with much probability to be the course of such displacements. Here, then, was the first important recognition of the tectonic nature of earthquakes, and, as a consequence, the Austrian school of seismologists has since endeavored to examine earthquakes in the light of the geological structure of the affected region.

It must be regarded as quite remarkable that the recognition of this fundamental fact was reached in Austria, for the opportunities offered by the Austrian field were by no means exceptional. In fact, the great surface faults which have been a feature of great earthquakes in other districts, have there been seldom observed. In New Zealand, for example, accompanying a heavy earthquake in 1856, an area of country comprising 4,600 square miles was suddenly upraised to form a visible escarpment varying from one to nine feet in height. This event was duly described by Lyell, who, in the eleventh edition of his widely read "Principles of Geology" reported this and other similar cases apparently without seeing that they throw any discredit upon the centrum theory.

In 1884[1] Gilbert, in a brief note, explained the earthquakes characteristic of the Great Basin of the western United States as due to the interrupted jolting uplift of the mass of the mountains by vertical thrust. The stresses tending to uplift the range aided by a fissure already in existence, accumulate until they overbalance the starting friction upon the fissure, when through movement the strain is relieved and the potential energy of the system reduced. In a later note published in 1890[2] he showed that during the earthquake of 1872 in the Owen's Valley, California, the ground was moved in strips both vertically and horizontally.

In 1893 Kotô, describing the great Japanese earthquake of 1891, in referring to earlier earthquake rents within the same district said:

> The event of October, 1891, seems to me to have been a renewed movement upon one of these preëxisting fissures—the Neo Valley line of fault, by which the entire region lying to the right of it not only moved actually downwards but was also shifted horizontally towards the north-west for from one to two metres along the plane of dislocation. This vertical movement and horizontal shifting seem to me to have been the sole cause of the late catastrophe.[3]

Without the aid of surface faults, Leonhard and Volz, in 1896, expressed clearly the idea that the Silician earthquake of 1895 was the result of an adjustment among orographic blocks or *Schollen*. Their statement was:

[1] *Amer. Jour. Sci.*, Vol. 27, 1884, pp. 49–53.
[2] Mon. I., U. S. Geol. Sur., pp. 360–362.
[3] *Jour. Coll. Sci.*, Tokyo, Vol. V., 1893, p. 329.

We must, therefore, regard the cause of the earthquake of June 11, 1895, as a movement of the Nimpt complex of orographic blocks, which occurred along the southern and eastern fracture margins.[4]

The great Indian earthquake of 1897 was thoroughly examined from the geological side with results which seem to have afforded indication of the movement of the ground in individual blocks. This, however, was not the theory adopted by R. D. Oldham, who wrote the report upon the earthquake, apparently for no other reason than that it seemed to require an expansion of the affected area. In consequence, the unique hypothesis was offered that the earthquake was due to a movement upon a thrust plane beneath the affected region. The mental attitude of Dr. Oldham is brought out in the following paragraphs from his report in modification of his choice of theory:[5]

Though apparently the most probable this is not the only possible, hypothesis. The surface features of the Assam range, described in the last chapter, are compatible with, in some respects they suggest, the idea that these hills are what the German geologists call Schollengebirge, that is, mountains which have arisen from straight up and down thrusts, instead of from lateral compression, like the Alps and Himalayas. *If this be so, the faults by which the fault scarps are formed would be normal faults,*[6] and so far from there having been any compression, the elevation of these hills would have been accompanied by an extension of the surface. The state of strain, too, which preceded the earthquake would have been one of tension and not compression.

The mechanism of the production of this form of mountain is not properly understood, and a condition of tensile strain in the crust of the earth would be still more difficult to explain, but the fact of the existence of such mountains and structures cannot be gainsaid, so the possibility of the state of tensile strain they imply must be allowed.

If such is the nature of the Assam range, and of the cause of this earthquake, there would be no thrust-plane underlying it, and the focus of the earthquake would have to be regarded as a complex one. That is to say, there would be no general focus, but a number of independent ones, along each fault, and the magnitude of the earthquake experienced would be due to the simultaneous occurrence of a number of earthquakes of various degrees of severity.

Whether we regard the focus as a thrust-plane, or as a network of faults, it practically covered an extensive area.[7] The hypothesis of a thrust-plane

[4] *Zeitsch. f. Erdkunde z. Berlin,* Vol. 31, 1896, pp. 1–21.

[5] R. D. Oldham, "Report on the Great Earthquake of 12th June, 1897," *Mem. Geol. Surv. India,* Vol. 29, 1899, pp. 165–168.

[6] The italics are mine.—W. H. H.

[7] The italics are mine.—W. H. H.

is the simplest to work with, as also the most probable, and it is that which has been adopted in the following pages.

As we shall see, the fundamental difficulty which stood in the way of the acceptance of the *Schollen* idea at the time Oldham was writing, has since been removed by the "distant" studies of earthquakes (see below, p. 285), and the theory of a thrust-plane, which he chose to adopt, has remained without any support in later work.

Additional and important contributions toward the fault-block theory of earthquakes have crowded about the beginning of the twentieth century. In the year 1900, Yamasaki, in describing the great earthquake of northern Honshu, which occurred in 1896, gave as its cause the movement on two visible displacements which opened on opposite sides of the mountain mass.[8]

Two long lines of fracture were discovered by me to be the cause of the Riku-U. earthquake. . . . They lie on the two sides of the mountain axis of the Central chain, and so this earthquake offers an example of the longitudinal quakes (*Längsbeben*) which but seldom occur.

Thoroddsen, in a report which reached the scientific world first through a German abstract of the year 1901,[9] was able to show that during each of the five heavy shocks of the South Icelandic earthquakes of 1896, a separate block of country had been shaken. These several areas were all included in a low plain walled in by a rampart of mountains, and with a single exception they were contiguous areas which did not overlap.

Each of the heavy shocks was limited to a circumscribed area which was made evident by a mass of collapsed houses, and from this the earthquake waves were propagated outward in all directions.

. . . .

The ground beneath the low plain is probably separated into individual parts and the continued movement on these cross lines [across the main fissures on which the volcanoes of the island are ranged.—W. H. H.], as well as the faults between the individual parts, appear to be the causes of the many earthquakes of this district. If one studies the statistical tables of the ruined houses from each shock [given in Icelandic report.—W. H. H.] it is seen that the individual areas are somewhat sharply delimited; while upon them nearly everything was destroyed, the damage outside was relatively small.

[8] N. Yamasaki, *Pet. Mitt.*, Vol. 46, 1900, pp. 249–255, map.

[9] *Pet. Mitt.*, Vol. 47, 1901, pp. 53–56. The full report had appeared in the Icelandic language two years earlier.

Writing in 1902 Professor John Milne, who has done so much to advance seismology, gave expression to his views upon the cause of the larger and smaller earthquakes:[10]

The earthquakes to be considered may be divided into two groups—first, those which disturb continental areas and frequently disturb the world as a whole, and secondly, local earthquakes which usually only disturb an area of a few miles radius and seldom extend over an area with a radius of 100 or 200 miles.

These former I shall endeavor to show are the result of sudden accelerations in the process of rock-folding accompanied by faulting and molar displacements of considerable magnitude, whilst the latter are for the most part settlements and adjustments along the lines of primary fractures. The relationship between these two groups of earthquakes is therefore that of parents and children.

Professor Milne's studies of "distant" earthquakes had revealed the fact that the world-shaking earthquakes most frequently occur upon the floor of the ocean.

When a world-shaking earthquake takes place, and its origin is suboceanic, we occasionally get evidence that this has been accompanied by the bodily displacement of very large masses of material. For example, seawaves may be created which will cause an ocean like the Pacific to pulsate for many hours.

To indicate the grand scale of the mass movements of the crust upon the continental areas, a list of twenty-two larger disturbances was compiled by Milne and the following important conclusions drawn:

If it can be admitted that world-shaking earthquakes involve molar displacements equal in magnitude to those referred to in the preceding list, . . . then, in the map showing the origins of these macroseismic effects, we see the districts where hypogenic activities are producing geomorphological changes by leaps and bounds.

The sites of these changes are for the most part suboceanic troughs. When they occur, the rule appears to be that a sea becomes deeper, whilst a coast-line relatively to sea level may be raised or lowered. For nearly all the regions of the world where they take place we have geological and not unfrequently historical evidence that the more recent bradyseismic movements have been those of elevation. This elevation, however, only refers to the rising of land above sea-level, while the mass displacements seem to be accompanied by sudden subsidences in troughs parallel to the ridges where rising has been observed. In short, at the time of a large earthquake, two

[10] "Seismological Observations and Earth Physics," *Geogr. Jour.*, Vol. 21, 1903, pp. 2, 9, 11.

phenomena are simultaneously in progress. A suboceanic trough may suddenly subside, whilst its bounding ridge may be suddenly increased in height, and the concertina-like closing of the trough may account for the sea-waves.

Dutton, in 1904,[11] included in his classification tectonic earthquakes, and by supplying data concerning the earthquake of Sonora in 1887 contributed an additional example of uplift *en bloc* of a mountain mass accompanied by a great earthquake. Of this range, the Sierra Teras, he says:

In other words, the range seemed to have been uplifted several feet between faults on either flank.

Yet the implication in the context is that these observations are hardly decisive, and in a paper read before the National Academy of Sciences in 1906[12] it is made clear that Dutton at this time still adhered strongly to a modified centrum view to which he had contributed in 1889 in his report upon the Charleston earthquake of 1886.

The Dutch geologist, Verbeek, in 1905 published a catalogue of the earthquakes of the island of Ambon in the East Indian Archipelago, together with a full account of the heavy earthquake which caused much damage upon the island on January 6, 1898.[13] His study of the distribution of the damage resulting from the latter quake brought out the fact that the shocks were largely limited to narrow zones on either side of a main fault running in a north and south direction across the island, and to similar zones about three additional faults which cross the first nearly at right angles, the stronger shocks belonging with the first mentioned displacement. Of this north and south zone he says:

The terrane most disturbed, which one designates "*the pleistoseismic area*" does not here have the form of a circle or of an ellipse, as in the case of so many earthquakes, but that of a long band relatively straight, which shows clearly that we have here to do with a *tectonic quake;* now since we have shown above in the description of the geology that there is at the south of Ambon a fault which is prolonged to the north through Ambon and southward . . . to the southern coast, it is altogether natural to attribute the earthquake to a new dislocation along this cleft or fault of the

[11] "Earthquakes in the Light of the New Seismology," 1904, p. 55.

[12] "Volcanoes and Radio Activity," Englewood, N. J., 1906, p. 5.

[13] R. D. M. Verbeek, "Description Géologique de l'isle d'Ambon," Batavia, 1905, pp. 300–323.

earth's crust. Since the formation of this cleft, which is at least of pre-Cretaceous age, doubtless movements have often occurred which continue even to our time. . . .

1906

In the following year the Count de Montessus de Ballore, who had already become known as a seismologist of reputation by reason of his masterly essay upon the distribution of seismicity over the globe, brought out a comprehensive work entitled "Seismic Geography." In this volume, as a result of the study of no less than 170,000 recorded shocks of earthquake, their distribution within each province was analyzed by new and ingenious methods of combination. In each case the known faults of the district under consideration were discussed, and so far as possible, their relation to the seismic distribution was brought out.[14]

Much the clearest demonstration of the adjustment of portions of the earth's crust as individual blocks, and here by well-demonstrated changes of level, is to be found in a paper by Tarr and Martin upon the results of earthquakes in Alaska in the fall of 1899.[15] Some portions of the coast were found to have been elevated, and other smaller ones to have been depressed. The sea, which here cuts up the district by a number of fiords, permitted the changes of level to be measured by the height of the abandoned shore lines of 1899. In the absence of earlier soundings or of correct maps, the submerged areas were determined with much less precision, though forests now below sea level bear abundant testimony to the local direction of the earth movement. Still older abandoned shore lines, appearing as notches above the raised beach of 1899, proved that the latest elevation is but one stage in the progressive, though interrupted, general uplift of the region. Tarr and Martin's statement of their view is as follows:

Briefly summarizing the inferences which the facts seem to warrant, we conclude that in 1899 there was a renewal of mountain growth, uplifting that part of the mountain front bordering the Yakutat bay inlet to different amounts—7 to 10 feet in the southeast side of the bay, and 40 to 47 feet on the northwest side. This uplift occurred all within a little over two weeks and mainly on a single day (September 10). It was complicated by move-

[14] "Les tremblements de terre; Géographie séismologique," Paris, 1906, pp. 475.

[15] "Recent Changes of Level in the Yakutat Bay Region, Alaska," *Bull. Geol. Soc. Am.*, Vol. 17, 1906, pp. 29–64, pls. 12–23.

ments along secondary fault lines, which produced at least three (and perhaps more) major blocks. . . . The first and largest of these blocks, . . . is apparently titlted upward toward the southwest.

Accompanying this faulting was a minor fracturing apparently due to local adjustments in the tilted blocks. Doubtless this minor fracturing is much more common than our observations indicate, for it was discovered in more than half our expeditions into the interior when we went out of the valleys away from the sea coast.

The evidence accumulated for the tectonic origin of earthquakes and their inseparable connection with the process of faulting in rock strata, has shown that seismology must be considered as a part of tectonic or structural geology—that part, namely, which is concerned with the recent and present-day history of the earth. So soon as this fact receives general recognition, the field of study must be added to that now explored by geologists. For their loss in this quarter elasticians will be more than compensated by the enlarged opportunities which are now offered them for studying earth waves as they are registered at a distance upon the newly devised earthquake instruments.

Recognizing, then, that earthquakes manifest the time of operation of these larger mass movements of the earth's crust which have brought about changes in level as well as changes in horizontal position in connection with faulting, it becomes necessary to place the subject *en rapport* with the latest that has been learned in the wide field of tectonic geology. This treatment of earthquakes as a part of tectonic geology was attempted by the present writer in two monographs published in 1907 in connection with a description of the Calabrian earthquake of 1905,[16] and later, in the same year, in a treatise upon seismic geology.[17]

Having in mind the fact that the traces of fault planes are but rarely exposed to view, and in only a small percentage of cases possible of determination from purely geological studies, the investigation of the Calabrian earthquake was directed toward determining whether, (1) there are lines or narrow zones of special

[16] "On Some Principles of Seismic Geology," with an introduction by Eduard Suess. "The Geotectonic and Geodynamic Aspects of Calabria and Northeastern Sicily," with an introduction by the Count de Montessus de Ballore. *Gerland's Beiträge z. Geophysik*, Vol. 8, 1907, pp. 219–362, pls. 1–12.

[17] "Earthquakes, An Introduction to Seismic Geology," New York, 1907, pp. 1–336.

intensity of shocks, (2) whether these are repeatedly the seat of special danger from successive earthquakes, and (3) whether such lines, if they exist, are expressed in the surface of the country as earth lineaments. The investigation showed that at the time of an earthquake the surface of the country affected is peculiarly sensitized to reveal the courses of hidden faults, which, if thus made apparent, may be designated *seismotectonic lines,* and that strong seismotectonic lines correspond in position to the striking lineaments of the country. In this we find a means of deriving through the study of the topography, the tectonic geology and the seismic history, an imperfect yet none the less a valuable map to display the architecture of each seismic district.

It is a curious illustration of earlier misdirection of effort, that up to the year 1907 no detailed map of the fault system within an area disturbed by destructive earthquake had been attempted. The maps which best display the disposition of adjusted fault blocks were the small-scale charts by Thoroddsen and by Tarr and Martin. In the summer of 1907, at the writer's suggestion, the expert topographer and geologist, Mr. W. D. Johnson, of the U. S. Geological Survey, prepared accurate maps of the surface faults of certain areas disturbed during the Owen's Valley earthquakes of 1872, which maps were published in part during the same year.[18] The sudden changes of displacement on individual faults and the mosaic-like structure of the disturbed region were thus brought out with a clearness and accuracy never before attained.

Seismological science may be said to have suitably celebrated its emancipation from the bondage of the centrum theory, when in 1907 there was published from the pen of the Count de Montessus de Ballore the most comprehensive treatise upon the subject.[18a] This book recognized the adjusted fault block theory as the best available working hypothesis of the science, and with a grasp of the subject which was based upon a lifetime of study, and upon a quite unparalleled knowledge of the literature, earthquakes were so treated as to make the work the one authoritative reference book of the science.

[18] In the author's "Earthquakes," Figs. 23, 45 and 64. More complete maps will appear in a special monograph.

[18a] La Science Séismologique, Paris, 1907, pp. 579.

The common characteristic of all phases of the modern tectonic theory of earthquakes, the evolution of which we have now largely traced, is that the adjustments in position or attitude of sections of the earth's crust are regarded as *the proximate cause and not the effect of the shocks themselves.* So far as molar movements have been recognized by the advocates of the centrum theory, they have been regarded as the *direct consequence of volcanic or explosive shocks emanating from a deeper-seated origin.* Two recent papers of a somewhat speculative nature, prepared by an astronomer, have sought the cause of earthquakes in a leakage from the bottoms of the oceans.[19]

The Relation of Earthquakes to Volcanoes.—As already pointed out, the earliest of the generally accepted theories of earthquakes connected them directly with volcanic action, and this idea has survived in the centrum theory. The tendency of later study has been to indicate that while both betray a certain relationship to each other, this is not often of such a nature as to call for a quick response of the one phenomenon to the other. Regions of volcanoes are subject to earthquakes, yet some of the heaviest earthquakes have affected a region distant from any volcanic vents. Again, most great volcanic outbursts are inaugurated by light earthquakes, but great earthquakes produce as a rule no perceptible immediate effect upon the activity of neighboring volcanoes. Thus, for example, during the late Messina earthquake, which was so heavy about the slopes of Etna, that volcano showed no sympathetic response. Catalogues setting forth the seismic and volcanic activity within any province betray, however, certain periods of years during which both seismic and volcanic activity are at either a maximum or a minimum; though within these periods no close time relation of the one phenomenon to the other is apparent. In short, it would appear

[19] T. J. J. See, A.M., Lt.M., Sc.M. (Missou.), A.M., Ph.D. (Berol.), "The Cause of Earthquakes, Mountain Formation and Kindred Phenomena Connected with the Physics of the Earth," Proc. Am. Phil. Soc., Vol. 45, 1907, pp. 274–414. "Further Researches on the Physics of the Earth, and especially on the Folding of Mountain Ranges and the Uplift of Plateaus and Continents Produced by Movements of Lava Beneath the Crust Arising from the Secular Leakage of the Ocean Bottoms," *ibid.*, Vol. 47, 1908, pp. 157–275.

that both earthquakes and volcanic activity are different indications of the operation of a more fundamental geological process—mountain formation, with its concomitant manifestation in changes of level.

Going back in the direction of the ultimate cause of mountain building, we are probably correct in assuming that it is a consequence of the contraction of volume of the planet and the wrinkling of the outer shell, as that shell adjusts itself over the diminished volume of the core beneath. In the past much confusion has arisen from assuming that flexuring has taken place within the outermost shell of the earth, and that the faults discovered are an incident to the folding process *within one and the same set of beds.* Thus we have come to speak of "dip faults" and "strike faults," "longitudinal faults" and "cross faults." Later studies have shown that the processes of folding and of faulting within rocks take place under different conditions of load corresponding to different depths below the surface; and that, therefore, the folding which accompanies the rise of a mountain range is so deeply buried beneath the roots of the range that it can be laid open for study only after a blanketing layer of rock some miles in thickness has been removed. Those mountains which are growing to-day—such, for example, as the Sierra Nevadas of the Pacific border of our own country—are being pushed up in blocks which are outlined by steep faults. The elevation goes on spasmodically, and each successive uplift causes a jolt which is manifested as an earthquake more or less destructive, according as the movement is of large or of small amplitude. Deep below the surface, the rising blocks of the crust rest upon arches of folds which a future generation of geologists may be privileged to study after a layer of the present surface some miles in thickness has been carried away. Those parts of the earth's crust which are not shaken by earthquakes are, in the language of de Montessus, no longer living—they are dead.

Not only are earthquakes the indication of changes in level such as accompany the process of mountain growth, but active volcanoes are now recognized to afford evidence of the same movements. Wherever mountain ranges are now rapidly growing, there active volcanoes are to be found. The full significance of this fact

is only beginning to be appreciated. Fortunately this hypothesis may be fitted to the now quite generally accepted view that the earth is essentially solid throughout, and is maintained in that condition at great depths below the surface by the high pressure from the superincumbent material. Now the arching of strata in the process of folding is competent to lift the load from underlying rocks, so that wherever their temperature is such that fusion would occur at the surface, a reservoir of molten lava is produced and will be brought to the surface from the action of gravity whenever a path is open for it. A reason is thus found for the presence of lava bodies at moderate distances only from the surface in those districts where the process of mountain building is in operation.

The Mesh-like Distribution of Volcanic Vents.—The lineal arrangements of volcanoes and the dependence of this alignment upon the existence of fissures through the crust, seems to have been one of the earliest of geological observations, so soon as the less civilized continents had been scientifically explored. In Europe the systematic arrangement of volcanoes is much less strikingly displayed, and it was there in consequence a later discovery. The credit for having first recognized this important fact of observation is generally given to von Buch, because of his classical study of the Canary Islands. It seems probable, however, that Alexander von Humboldt, his friend and colleague in the field of geological exploration, was the first to make the observation. The latter showed that the volcanoes in the Cordilleran system of South and Central America furnish striking examples of such alignment. Von Buch, in his turn, emphasized this significant relationship, but found certain volcanic districts within which the alignment of vents was not apparent, and so he distinguished *volcanic chains* from *central volcanoes*. Other explorers like Dana and Darwin soon added confirmation of a linear arrangement from the regions which they had individually visited. Dana, a member of the Wilkes Exploring Expedition, brought out the lineal arrangement of the Polynesian Islands and showed that all these were alike rows of partly submerged volcanic peaks.[20] Darwin, during his voyage on the

[20] "Manual of Geology," pp. 37, 282.

"Beagle" made observations[21] which advanced the knowledge of volcanic distribution, as we shall see, very nearly to that of the present day.

As early as 1825, that pioneer and master of vulcanology, Paulett Scrope, discussed the arrangement of volcanoes in the following manner:[22]

> The generality of volcanos have a decided linear arrangement; one vent following the other in the continuation of the same straight or nearly straight line; and when volcanos have been formed on neighbouring points out of this principal line, they are in almost all cases situated upon other rectilinear bands parallel to the first.

Later Scrope expressed his doubt of the existence of v. Buch's class of central volcanoes, for which it had been claimed no alignment could be discovered.[23] In 1844 Darwin proved the existence of neighboring parallel fissues outlined by volcanoes, and was further able to show by his studies of the Galapagos Islands that the arrangement of the vents there brought out the existence of a network of fissures composed of two rectangular series with the principal vents at the intersecting points.[24] The directions of the two series were northwest by north and northeast by east. Virlet d'Aoust had already discovered the same kind of structure in the arrangement of the volcanoes within the Grecian archipelago.[25]

Inasmuch as a mesh-like disposition of volcanic vents within a network is of the first importance in its relation to the mass displacements which occasion earthquakes, it is pertinent to examine the more recent literature of the subject with a view to establishing its truth or falsity. The newer and more accurate methods for preparing maps which have been introduced since the time of Darwin, make such a review at the present time in every way desirable. There are two regions especially which have been recently carefully studied by authorities of the first rank in the field of vulcanology. I refer to Iceland, surveyed at his personal expense throughout a

[21] "Geological Observations on the Volcanic Islands, etc.," 1844, pp. 140–145.

[22] "Considerations on Volcanos," London, 1825, p. 126.

[23] "Volcanos," London, 1862, p. 258.

[24] *L. c.*, edition of 1900, p. 131.

[25] *Bull. Soc. Geol. France*, Vol. 3, 1832–33, pp. 103–110, 201–204.

period of seventeen years by Professor Thoroddsen of Copenhagen, and the islands of the East Indian Archipelago, surveyed for the Dutch Government by the distinguished geologist, Verbeek. Of the Icelandic volcanic region Thoroddsen says:[26]

Of larger eruption fissures and crater chains I have found 87, all of postglacial origin; . . .

. . . The many fissures which are common to several districts can not possibly be entered upon a map of small scale; the terrane is often so divided by clefts that both within the flat country and upon the slopes of mountains it appears to be separated into numerous narrow strips some kilometers in length. . . .

. . . Between the numerous non-volcanic and the volcanic clefts which have poured out important streams, no difference is to be noticed; an ordinary cleft may suddenly become volcanic. . . .

. . . Where larger fissure systems cross, there are often found large

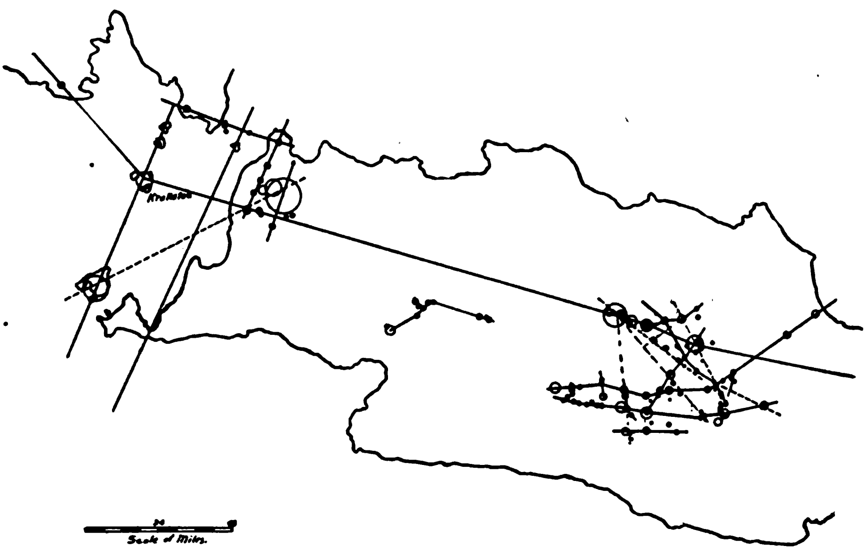

Fig. 1. Map showing arrangement of volcanoes in the western part of the Island of Java. (After Verbeek.)

volcanoes, as for example the largest volcano in Iceland, Askja, with a crater of 55 sq. km. area situated at the intersection of the southland fissure running NE.-SW. and the northland one trending N.-S.

[26] "Die Bruchlinien Islands und ihre Beziehungen zu den Vulkanen," *Pet. Mitt.*, Vol. 51, 1905, pp. 1–5, map pl. 5.

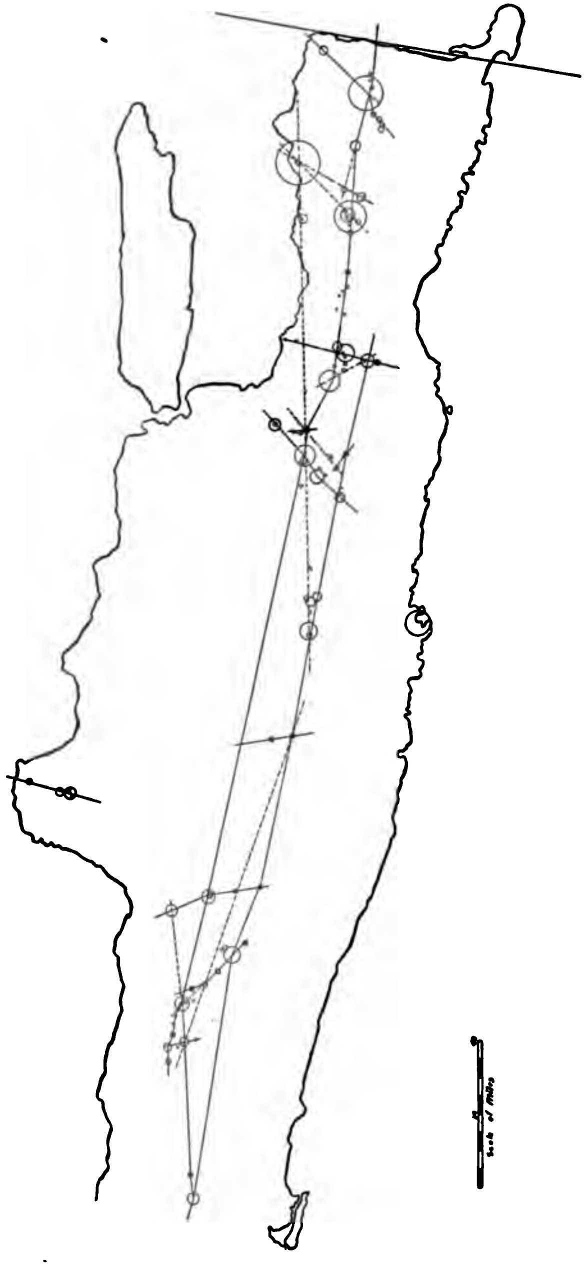

FIG. 2. Eastern portion of the Island of Java showing mesh-like arrangement of the volcanic vents. (After Verbeek.)

With the exception of the report on Krakatoa the five monographs and accompanying grand atlases which have been issued by the Geological Survey of the Dutch East Indies under the direction of Dr. Verbeek, seem to be but little known; yet they contain the results of extended and detailed surveys within one of the world's most interesting volcanic regions.[27] Nowhere have such trustworthy data been compiled which permit of a thorough study of the arrangement of volcanic vents. Clearly aligned upon fissures the map of Java displays the elements in the intersecting volcano network, as may be seen from atlas drawings reproduced in Figs. 1–2.

Though more accurately worked out, it does not appear that these instances of intersection of volcano rows is exceptional. Felix

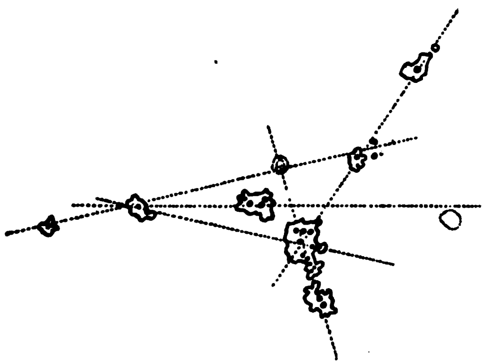

FIG. 3. Map to bring out the arrangement of volcanic islands and submerged volcanic peaks in the Lipari group.

and Lenk[28] have explained the prominence of the mighty volcanoes of Mexico, Popocatepetl, Ajusko and Nevada di Toluca, as due to their location at the intersection of important fissures, though the warrant for this has been questioned by others. The volcanic Lipari Islands of the Mediterranean, which were formerly regarded as

[27] Verbeek, "Sumatra's Westkust" (Dutch language), Batavia, 1883, 674 pp., atlas of 16 maps. Verbeek, "Krakatau," Batavia, 1885, 567 pp., atlas of 25 pls. Verbeek et Fennema, "Description Géologique de Java et Madoura," Amsterdam, 1896, two volumes, 1,183 pp., atlas of 24 maps. Verbeek, "Description Géologique de l'ile d'Ambon," Batavia, 1905, 323 pp., atlas of 10 maps. Verbeek, "Rapport sur les Moluques," Batavia, 1908. 1844 pp., atlas of 20 maps.

[28] *Zeitsch. d. deutsch. geol. Gesell.*, Vol. 44, 1892, pp. 303–326.

built up on radial fissures going out from the ruptured center of a depressed area, reveal a regular plan with the volcanic peaks and craters at the crossing points of intersecting lines, so soon as the submerged cones are brought into the problem (see Fig. 3).[29] The volcanoes of Italy and surrounding waters furnish an example of a much larger network within which the vents are located at intersecting points.[30]

What is true of the arrangement of ordinary volcanic cones within individual provinces, is repeated in the case of the monticules or parasitic cones which are built up upon the flanks of larger composite volcanoes, such, for example, as Etna.[31] To some extent a similar arrangement may be inferred on a far grander scale than any that has been mentioned, as in the longer trains of the volcanic islands. As long since pointed out by Neumayr, the volcanic island, St. Helena, is located at the crossing point of two long lines of widely separated volcanoes, one trending NE.–SW., and the other NW.–SE. (See Fig. 4). One of these, the well known "Cameroon fissure," bisects the Gulf of Guinea and includes the volcanic islands, St. Helena, Annobom, Sao Thomé, I. do Principe, and Fernando Po. On the land this fissure is continued in a striking manner by the fault bridge which ends in the Tschebitschi, 2,000 meters high, which then drops suddenly to the level of a low plain less than 200 meters above the sea. The volcanotectonic line which intersects this striking lineament at St. Helena, includes Ascension, one of the eastern cones of St. Paul's Rocks and a conical, submerged elevation upon the sea floor, almost under the tropic of Capricorn about 800 kilometers southwest of Amboland.

In addition to these two fissure directions, a third is like them strikingly characteristic of the African continent, as shown by the remarkable north and south lines of volcanoes and rift valleys in central Africa east of the Nile. To these three prevailing directions, northwest-southeast, northeast-southwest, and north-south, must be added a fourth less common direction, namely, east-west. Simmer

[29] Hobbs, *Gerlands Beiträge z. Geophysik,* Vol. 8, 1907, pp. 316–317.

[30] *Ibid.,* pp. 315–316, smaller map of pl. 3. See also Suess, "The Face of the Earth," Vol. 1, p. 144.

[31] Hobbs, *l. c.,* pp. 348–349, pl. 10.

in a noteworthy compilation[32] has shown that these directions are brought out for the African continent not only in the lines of

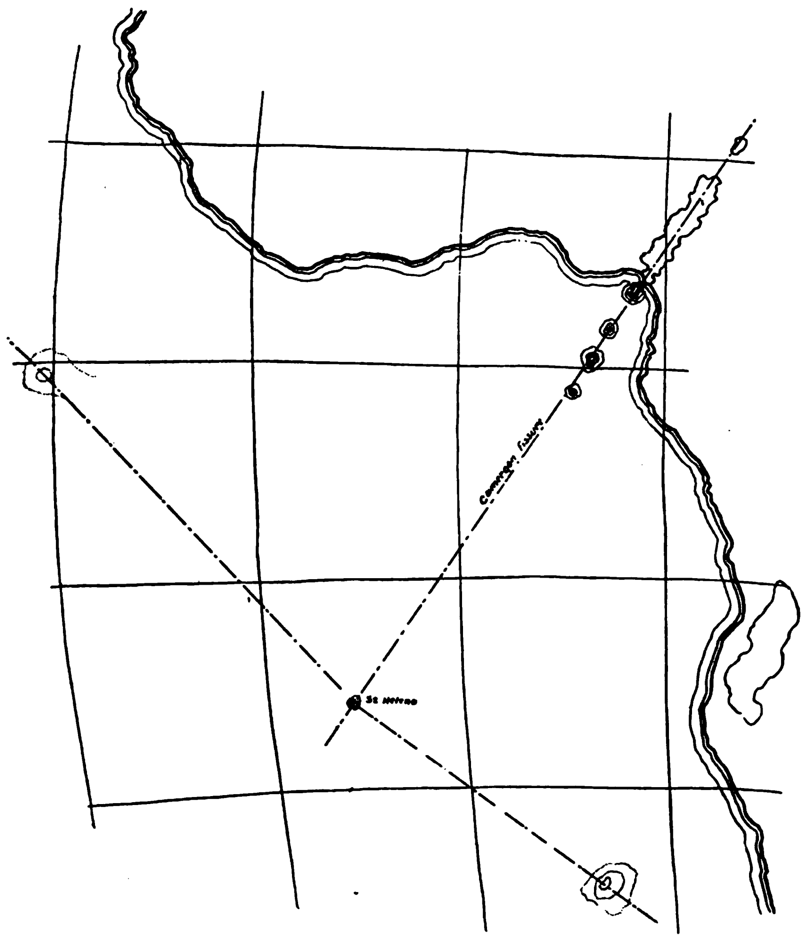

FIG. 4. Volcanotectonic lines which cross at St. Helena.

volcanoes but by the fracture systems revealed in the rocks, so far as they have been studied. It is interesting to note that these

[32] "Der aktive Vulcanismus auf dem Afrikanischen Festlande und den Afrikanischen Inseln," *Münchener Geographische Studien*, No. 18, 1906, 218 pp.

directions are also the dominant ones in the fracture system of North America.[33]

A number of papers of a controversial nature have appeared notably by Branca[34] in opposition to the view that volcanoes are aligned upon fissures, but inasmuch as they deal with districts in which the evidence is more or less equivocal they need not be considered here. The problem of arrangement of volcanoes must be solved not in southern Europe nor on the Mexican plateau border, but in the volcano gardens of the world, such as Iceland or Java.

Volcanic Extrusions in Relation to Block Adjustments.—Clarence King in his description of the area included in the Fortieth Parallel Survey,[35] an area divided by vertical faults into great blocks which underwent adjustments at the close of the Miocene, has furnished a classical instance of the relation of volcanic outflow of lava to block movement. He says:

> Single ranges were divided into three or four blocks, of which some sank thousands of feet below the level of others. The greatest rhyolite eruptions accompanied these loci of subsidence. Where a great mountain block has been detached from its direct connections and dropped below the surrounding levels, there the rhyolites have overflowed it and built up great accumulations of ejecta. Whenever the rhyolites, on the other hand, accompany the relatively elevated mountain-blocks, they are present merely as bordering bands skirting the foothills of the mountain mass. There are a few instances in which hill masses were riven by dykes from which there was a limited outflow over the high summits—but the general law was, that the great ejections took place in subsided regions.

The study of the great rifts of eastern Africa seems to have shown that the volcanoes which have there been built up, are similarly related to the sinking of the great strips of country which have caused the chief inequalities of the general surface.[36] The two

[33] Hobbs, "The Correlation of Fracture Systems and the Evidences of Planetary Dislocations within the Earth's Crust," *Trans. Wis. Acad. Sci.*, Vol. 15, 1905, pp. 15–29.

[34] W. Branca, "Zur Spaltenfrage der Vulkane," *Sitzungsber. Ak. Wiss.*, Berlin, 1903, pp. 748–756.

[35] "United States Exploration of the Fortieth Parallel," Vol. 1, Systematic Geology, 1878, p. 694.

[36] Ed. Suess, "Die Brüche des östlichen Afrika," *Denksch. Weiner Akad., Math. Naturw. Kl.*, Vol. 58, 1891, pp. 555–584.

chains of volcanoes in Mexico as mapped by Sapper[37] seem to be similarly associated with the great rift valley lying on the western border of the Mexican plateau.

It is in Iceland, however, that the most extended studies have been made of the most interesting field, in which the relation has been worked out with the greatest thoroughness.[38] Says Thoroddsen:

> One gains the impression that the form of the surface has no significance as regards the volcanic force, which breaks out above upon the ridges, as well as below in the valley, yet the volcanoes are always found associated with areas which are either sinking or have sunk.
>
> The lava stream Ögmundarhraun in Krisnoik, which dates from about 1340, was poured out from two parallel clefts. The southernmost portion of this stretch of country between the clefts after the beginning of the eruption sank about 66 meters, and one side of the western fissure rose like a vertical wall with four half craters open at the brink, the other halves having sunk. At the end of the cleft is a visible dike which leads up to the row of craters.
>
> Where great fractures or faults are present in the crust, the volcanic forces have not always made a single passageway through them, but in the vicinity on parallel clefts, often upon the high fracture margin; thus one fracture line 50 km. long extends without volcanoes from Krisnoik to Hengill, at which place the north side is sunk 200 to 300 meters; parallel with this is here found above at the margin of the cliff an almost uninterrupted series of craters which have formed not alone upon a single fissure but over several slices and small fissures running parallel to one another. A similar phenomenon is to be observed on the southern fracture margin of the peninsula of Snaefellsnes where the craters are mainly found above upon the edge of the bluff. Often, also, the reverse is the case, as for example, in the Odadahraun, where the rows of craters for the most part extend along the bases of the mountain chains, which rise as horsts from the sunken ground on either side; a like example occurs at Myvatu, although here the rows of craters occur at times above upon the ridge.

In none of these cases have we evidence that the eruptions coincided closely in time with the earthquakes which must have accompanied the movements of the earth strips between their bounding faults, but the relationship of the one phenomenon to the other could hardly be more clearly proven. Summing up the discussion, we note that volcanoes, no less than earthquakes, help us to find the positions of those fissures within the crust by which it is separated

[37] "Ueber die raümliche Anordnung der Mexikanischen Vulkane," *Zeitsch. d. Deutsch. Geol. Gesell.*, 1893, pp. 574–577.

[38] *L. c.*, p. 3.

into a mosaic of blocks, and that these lines of fracture may therefore be designated *seismotectonic* or *volcanotectonic lines* or simply *lineaments* according as they are revealed by earthquakes, by volcano rows, or by topographic and geologic peculiarities.

A Possible Explanation of "Volcanic Earthquakes."—Writing before 1885 Suess distinguished two classes of earthquakes, the dislocation and the volcanic earthquakes, and to these Rudolph Hoernes added the type of in-caving earthquakes to cover especially some of the light shocks of the Dalmatian coast. If we were to supply a complete category of earthquakes it would be necessary to add further a type of cataract earthquakes to cover the occasional fall of limestone blocks in the Niagara cataract, as well as many other minor forms, such as blast shocks in mines, etc. In point of importance two classes only stand out sharply as they were originally announced by Suess, and the present writer has been of the opinion that even these may perhaps be subclasses only of a single phenomenon. The mechanics of volcanic eruption, so far as it applies to the cone, is now so well understood that we are able to connect the outflow of lava which marks the beginning of the grand stage of paroxysmal eruption in a composite cone, with the rending of the mountain and the opening of a fissure—a distinctly tectonic movement induced by the lava as it rises under the influence of gravity, aided perhaps by the expansive power of the associated steam. I believe we have been misled into supposing that the fissures which are thus opened are necessarily radial to the cone, since this would be presumed if the mass of the cone and its basement were throughout homogenous, with no preëxisting fractures, and were acted upon by hydrostatic pressure from the central shaft only.

Etna is a giant mountain rising nearly 11,000 feet directly from the sea, its diameter is more than twenty-five miles, and since the higher portions are so largely concentrated at the center, the average thickness of visible volcanic ejectamenta over the base of the cone is only about one half mile. Apparently, therefore, this superficial layer of volcanic material may play a relatively small rôle in the rending of the entire mass which accompanies an outflow of lava. So soon as we examine the lines of parasitic craters which

are distributed upon the flanks of the mountain, we find that the majority of these are not radial to the mass at all, but comprise a network. A notable instance of a line of craters not in radial relation to the central cone is furnished by the chain of Monti Segreta, Nocella, Pizzuta, Gervasi, Arso and Difeso. Nearly parallel to this chain is that of the Monti Mazzo, S. Leo, Rinazzi, Guardiola and Albano. A map of these and other monticules upon the flanks of Etna has been already published by the writer.[39] It is, therefore, not only possible, but extremely probable, that in many instances the earthquakes which so generally accompany the rending of a volcanic cone, are directly associated with the opening of, and perhaps a differential movement upon, those fractures in the basement of the mountain which are a part of the larger fracture system of the district. Lacroix has recently shown that a *network* of fissures appeared upon Etna in connection with the eruption of 1908.[39a]

The Conditions of Earth Strain During the Growth of Block Mountains.—If we consider any circumscribed portion of the earth's crust within which mountains are growing through the adjustment by individual blocks or compartments of the crust, it is necessary to assume that the superficies is increased during the process. Individual blocks may indeed be actually depressed as a consequence of the adjustment, but yet the average movement must be assumed to be upward rather than downward. Such a conclusion is, however, in contradiction of the generally accepted view that mountain growth comes about through a reduction of superficial area from secular cooling. This very obvious difficulty in the way of adopting the *Schollen* conception of mountain structure has been quite generally recognized, and we have already seen how Oldham, in seeking the cause of the great Assam earthquake, was led to reject the theory, even though the vertical faults and the differential changes in level were plainly to be observed.

In the opinion of the writer, the recent study of "distant" earthquakes by modern seismographs has removed this difficulty in the way of a general acceptance of the fault-block theory. By extend-

[39] *Gerland's Beitraege z. Geophysik,* Vol. 8, 1907, pp. 348–350, Pl. 10.

[39a] L'eruption de l'Etna en avril-mai 1908, *Revue générale des Sciences pures et appliquées.* 20ᵉ année, 1909, pp. 298–314.

ing our knowledge of surface displacements of the earth to the floor of the oceans, it has brought us a surprise; for we have learned that to these areas, by many regarded as so stable, belong a much larger proportion of the grander movements, and by presumption of the smaller ones as well. The recent study of the ocean floor through soundings, examined with reference to the loci of suboceanic quakes, has told us, further, that though the movements upon the land are generally upward, those upon the ocean bottom, on the contrary, are downward. The so-called "origins" of the oceanic quakings are most frequently the steep borders of the great sea troughs where the greatest depths have been revealed by soundings. Now it is as impossible to separate the idea of molar displacements from these great disturbances as it is to avoid the conclusion that since these troughs are now the deepest bottoms, this is a direct consequence of the repeated displacements which must accompany the quakings. It has, moreover, been a general result of direct observation, that with noteworthy local exceptions the sea-coasts are to-day undergoing elevation, and that the steeper coasts face the greater depths.[40]

It is difficult to avoid the conclusion that the general upward movement of the margins of the continental areas and the general downward movements of the near-lying oceanic floors are interrelated as parts of one general adjustment within the outer shell of our planet. This granted, there is no difficulty in conceiving of the rise of block mountains upon the continental borders, since the increase of superficies within the affected continental region is compensated by a contraction of area in portions of the sea floor which in the same general period are subsiding. A rise of block mountains to the accompaniment of an earthquake, if our theory of cause be correct, though it calls for an expansion of the surface, should reduce the superficies of the affected region *if measured on the surface of a sphere at its former level.* A renewed and sudden compression of the district is thus made possible through the action of the tangential compressive stresses within the contracting shell. The writer believes that evidence of such compression has been

[40] See, among others, G. Schott u. P. Perlewitz, "Lothungen I. N. M. S. "Edi" und des Kabeldampfers "Stephan" im westlichen Stillen Ozean," *Arch. d. deutsch Seewarte,* Vol. 29, 1906, pp. 5-11.

found in the case of most large earthquakes in the behavior of rails and bridges.[41]

Part II: The Outlook of Seismic Geology.

The Ultimate Cause of Earthquakes.—No one should be deceived into concluding that because we seem to have found some evidence of the nature of the process by which the external shell of our planet undergoes its adjustment at the time of an earth shock, we have thereby discovered the *ultimate* cause of earthquakes. That is a far deeper problem, to which the discovery of the *proximate* cause is but an initial stepping stone. It is in this field that the deeper secrets lie hidden. The outlook of the science indicates two lines of effort to be followed up. These are: (1) To make practical application of the knowledge already gained, and (2) to investigate with every possible improvement in method until we have so laid bare the laws of seisms that we may forecast the time, the place and the probable severity of future earthquakes with at least as much accuracy and forewarning as is now possible in weather prediction.

Earthquake Forecasts.—It is much to be feared that the science of earthquakes is to pass through a stage not unlike that in meteorology which ushered in the day of scientific prognostication. Judging from statements which have been published, a "Farmer's Almanac" of earthquakes and popular earthquake prophets may be looked for as a possibility of the near future. It will be well, therefore, to consider the nature of the earthquake forecasts which have been so widely advertised. Examined with care it is found that these, in so far as they have found any verification, apply to a single, though the most important, seismic zone, and that all are indefinite as to the time and largely so as to place. Dr. Omori, of Tokyo, after the California earthquake of 1906, made a forecast which he himself subsequent to its partial verification reported as follows:[42]

As to the probable position of the next great shock on the Pacific side of America I expressed my view that it would be to the south of the equator

[41] Hobbs, "A Study of the Damage to Bridges During Earthquakes," *Jour. Geol.*, Vol. 16, 1908, pp. 636–653.

[42] *Bull. E. I. C.*, Vol. 1, No. 1, p. 23.

(that is to say, Chili and Peru), as it was very likely that the seismic activity would extend to either end along the great zone in question, and as the coasts of the countries above named are often visited by strong earth convulsions.

About two months after the prediction was made occurred the Valparaiso earthquake, but at the same hour an earthquake of the same order of magnitude visited an area in the Aleutian Islands within the same seismic belt, though nearer and in the opposite direction from the one predicted. On the same grounds Lawson in a lecture read in March, 1907, said of the stretches between southern California and Central America, and between northern California and southern Alaska:

These strips, I believe, will be visited before long, and then the long line of this earthquake will be complete from Chili to Alaska.

The Guerrero earthquake in Mexico occurred only a few weeks later and bore out the geologist's faith in the soundness of his hypothesis.

The method upon which such predictions are based is already indicated in the quotations given. Briefly expressed it is the principle of immunity from shock for a considerable period after heavy earthquakes, combined with the conception of relief secured throughout an extended zone in sections by alternation. An extended zone on the earth's surface is recognized to be what might be called an orographic unit; that is to say, it is all undergoing progressive though interrupted elevation. Stresses tending to produce uplift are presumably cumulative and may be of varying amounts in different sections of the zone. The resistance to movement under the strain—whether due to the rigidity, to the vice-like compression, to the absence of suitable fissure planes on which the movement might occur, to the healing of such fissures by mineral matter, or to any other causes—may be assumed to be different in different parts of the zone. Relief of stress through sudden uplift should, therefore, occur first within some one section of the zone where stresses are greatest, resistance least, or both. The earthquakes furnish abundant proof of the general correctness of this view. Now it is simpler to assume that relief having been secured in one section of the belt, a certain lowering of the potential energy of the system of

stresses is to be expected in the near-lying sections on either side, particularly since the shock tends to discharge the system of strain as would a fulminate. On the theory of probabilities the area next to be relieved should be the most distant, providing stress has there been accumulated for an equally long period. The third and fourth steps in the cycle of release of strain should in position be intermediate between the first and second on one side or the other. Later steps in the "letting down" process should affect especially the still intermediate unrelieved sections of the zone.

This method, simple as it is in theory, permits of only the broadest generalization and, as already stated, has been tested in but one zone and for one cycle of relief. This zone is the great circle belt which surrounds the Pacific Ocean, and the cycle of relief seems to have begun with the Colombian earthquake of January, 1906. Only two months after this disturbance came the Formosa earthquake, in a province between one third and one half the distance around the planet. The area of the California earthquake, which occurred a month after that in Formosa, is intermediate between the first two, though nearer the first than the second. By examination of Fig. 5, which is drawn to scale, it will be noted that the distances separating the approximate centers of these and the later disturbances in the series, generally bear out the hypothesis that each later earthquake affects an area farthest removed from those sections of the zone which have already found relief.

The rapidity with which the steps in the process of securing relief have here succeeded to one another, lends strong support to the view that the zone in question should be regarded as a definite orographic unit, and that the stress-strain conditions within all except the southernmost portions were before relief began, remarkably uniform. The planetary order of magnitude of the movements would thus seem to be clearly indicated. The section of the zone last to be relieved was, it is interesting to note, one which had been partly relieved of stress during two earthquakes six years and four years before the main cycle of relief was inaugurated. The section which separates the district of the Aleutian from that of the Californian earthquake had also been visited by earthquakes seven years and six years previous to the main cycle of relief. The portions

of the zone in which the probability of heavy shocks is now most imminent, are the Japan-Kamschatka segment, the Peru-Bolivian segment, and the archipelago region to the southeast of Asia. Inasmuch, however, as between 1899 and 1903, 29, 12 and 41 heavy shocks had been registered by seismographs from the vicinity of

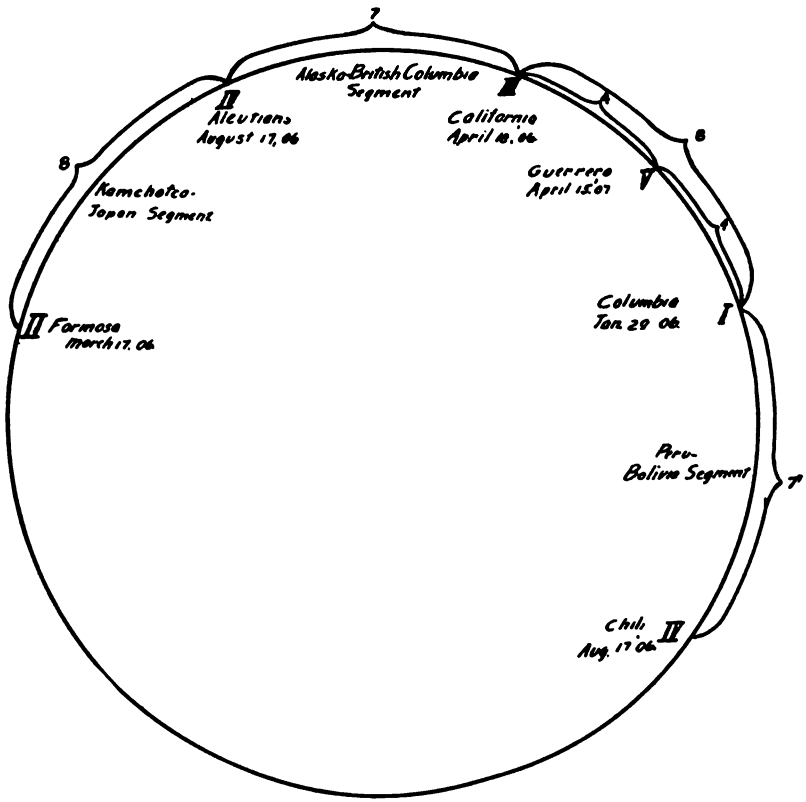

FIG. 5. Diagram showing the distances which separated the approximate centers of areas of the series of earthquakes within the circum-Pacific zone in the years 1906–7.

these three segments respectively,[43] the time may be long before the limit of strain may again be reached in them. The problem is thus far from simple and prediction would be extremely hazardous.

It should not be forgotten that prediction of any sort has thus

[43] Milne, *Geogr. Jour.*, 1903, map.

far been possible only within this circum-Pacific zone, which, at the time, is passing through a remarkable seismic history. It is little likely that any such sudden relief of strain will take place again in the same zone before a considerable period has elapsed.

Yet, outside this zone and within our own country, earthquakes of the first order of magnitude have visited the lower Mississippi Valley, the coastal plain in South Carolina and the valley of the St. Lawrence during the brief period that the country has been occupied by whites. Of these sections of country, as of most others, the only safe prediction that can now be made, is that districts already visited by historical destructive shocks, as well as some others, notably New England and the Middle States, will eventually suffer from disastrous earthquakes. To the time of such visitations we have not even a clue.

Periodicity of Earthquake Cycles.—The "letting down" of the potential energy of the system of stresses within the circum-Pacific belt, as brought out by the events of 1906–7, is, in the writer's belief, as regards its close sequence, an event without parallel in the history of seismic geology. Something approaching it appears, however, to have been in operation within a somewhat longer period in the other great seismic belt of the globe. Making all due allowance for the fact that our quite recent study of distant earthquakes has greatly extended our horizon, it still seems necessary to conclude that the present is a time of very exceptional seismic intensity.

So soon as we admit the planetary scale of these seismic disturbances and explain them as a result of mountain growth upon the borders of the continent, we are led to expect the existence of such maxima and minima of seismic intensity. If now we examine the history of earthquakes in those countries possessing the longest records, we find evidence in support of this view. The stronger earthquakes in Japan, which are on record for a period of fifteen hundred years, betray a strong tendency to group themselves. The 154 heavy earthquakes recorded in that country since the beginning of the fourteenth century may be divided more or less definitely into 41 groups separated by average intervals of 13½ years. In Kyoto a complete record has been kept for a thousand years. Here there was a strong maximum of destructive and strong earthquakes be-

tween the middle of the fourteenth and the middle of the fifteenth century, this maximum period being followed by a steady decrease to a minimum in the last half of the nineteenth century. Minor fluctuations reveal an average period of 6½ years, or about one half that revealed by the records for the Empire as a whole.[44]

The natural objection which would be raised to making use of these data for basing conclusions upon the behavior of the earth as a whole, is that the maximum of intensity in Japan may well have been compensated by a minimum in a neighboring district. What we need for basing our conclusions is a world catalogue of earthquakes extending over a sufficiently extended period. Thanks to John Milne and those who have followed his lead, we are now preparing such a catalogue, which is sure to permit of a definitive answer to the question of earthquake periodicity. Even within the first section of this catalogue, comprising as it does the thirteen years from 1892 to 1904, Milne believes he has made out a relatively short period with the maxima of world shaking in correspondence with the more abrupt changes in direction in the orbit of the earth's pole. On *a priori* grounds it is reasonable to connect seismic disturbances with sudden changes in latitude, and the further data upon the pole movement and the seismic world maxima, will be scrutinized with interest.

Possibilities of Future Prognostication.—It is too early to predict whether more satisfactory bases for future forecasting of earthquakes will be discovered, but the indications are certainly encouraging. Two, and perhaps three, lines of inquiry are already suggested. Most promising of these, is, perhaps, the study of terrestrial magnetism; for in a considerable number of instances, destructive earthquakes have been preceded by periods measured in hours and sometimes in days, within which the behavior of magnetographs was singularly abnormal. It seems likely that this change in magnetic conditions may sometimes be utilized as a warning signal. For solution of this problem the completion of the magnetic survey of the world, may be expected to contribute.

Evidence is not lacking that fore-shocks, or rather fore-tremors,

[44] Kichuchi, E. I. C. Pub., No. 19, 1904, pp. 11–13.

for they would appear to have an extremely small amplitude of vibration, are a fore-runner of most heavy earthquakes. These fore-tremors should not be confused with the preliminary tremors in the record of the distant seismograph, for they are of such small amplitude that they would probably not be registered by any instruments today constructed, except perhaps within the affected district itself. Our best evidence that such fore-tremors exist is furnished by the behavior of certain of the lower animals. In the opinion of the writer, such a body of evidence has now accumulated, that it can no longer be waved aside. Just as the sense of smell is so much more highly developed in the dog, for example, than it is in man, so there seems no valid reason for doubting that the detection of small motions by the lower animals may be by as much superior to the human sensibility. Dr. Omori has expressed his belief that seismographs will yet be made sufficiently sensitive to record these microscopic tremors. Just as a block tested in our experiments assumes very large deformations as it approaches rupture, so the earth structure may behave during a period which is as much longer in proportion as the time of augmenting the stresses exceeds that in our experiments. Judging from the recorded behavior of animals, it would not be surprising if the period during which warning may be possible on this basis, should prove to be a large fraction of a day, or even longer. If measurable deformation does occur as a result of the accumulated stresses long before the limit is reached, it may be possible in the case of those earthquakes particularly which result in horizontal shearing movements, to determine by frequent measurement of the distances which separate properly placed monuments, the approach of the strain limit. It is a subject which is at least worthy of investigation.

Since the days of Perrey, who devoted his life to an attempt to find a connection between earthquakes and lunar conditions, there have been those who have sought to connect seismic and volcanic disturbances with periods of special gravitational stress due to luni-solar phases. The most recent advocate of such a connection, is Perret,[45] who is so convinced that he has found the secret behind

[45] "Some Conditions Affecting Volcanic Eruptions," *Science*, Vol. 29, 1908, pp. 277–287.

the phenomena as to have ventured to predict for the year 1908, a grand eruption of Etna.[46] This eruption not having materialized, Perret has accepted the Messina earthquake as a substitute.[47] Assuming that his method is correct, it is possible to see how a period of seismic or volcanic activity might be predicted; the method, however, gives no clue as to what part of the earth's surface is likely to be thus affected. The predictions of the author of the theory have,

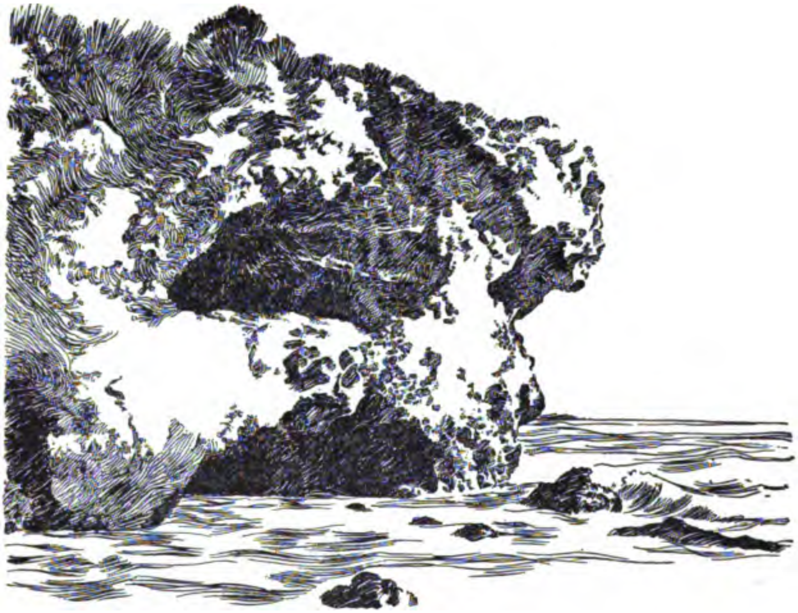

FIG. 6. Abandoned Sea Cave 10 feet above water on Coast of California. (After Fairbanks.)

on the whole, been less remarkable than the statements made by one of his supporters.[48]

Need of an Expeditionary Corps.—It may well occasion surprise that governments have been so slow to appreciate the necessity for providing means for the investigation of earthquakes. Our own government, which has shown such commendable generosity in providing the sinews for scientific investigation, has in this particular

[46] *The World's Work,* November, 1907.
[47] *Am. Jour. Sci.,* Vol. 27, 1909, pp. 322–323.
[48] Jaggar, *The Nation,* Vol. 88, 1909, pp. 22–23.

field lagged far behind other nations. In Japan since 1892 there has been an Earthquake Investigation Committee, and whenever a destructive earthquake is reported from any part of the world, Professor Omori, the secretary of the committee and its chief expert, is despatched by his government to prepare a report upon it. Under orders from the Japanese government, he is today in the vicinity of Messina engaged in a study of the latest great disaster. While these expeditions have been of value in securing information, the time has come when with the incease of our knowledge of earthquakes, something more than a reconnaissance survey is required. One man without assistants and without elaborate equipment, is today in no position to secure those more important data which alone can advance our knowledge of earthquakes beyond its present status. Today a scientific party should have at its disposal one or more surveying vessels—small gunboats or protected cruisers could be easily adapted for the purpose—provided with modern sounding apparatus and with a full equipment of necessary instruments. The crops of scientific workers should include skillful topographers and their assistants and all suitable instruments for preparing accurate topographic maps. The party should also include trained experts whose duty it should be, among other things, to map the distribution of the surface intensity of the shocks. An expeditionary vessel of the type described could be utilized upon occasion to study volcanic as well as seismic disturbances; such, for example, as the late eruptions in the Windward Islands. The seismic events of the years 1906–8, would have been more than sufficient to take up the attention of two surveying vessels with their corps of scientific workers.[49] In times of relative seismic inactivity the ships and their complements could be employed to advantage in work which will be more definitely indicated below.

A Service of Correlated Earthquake Observatories.—In addition to the study upon the ground, which may be expected to lay bare some important laws of seismic geology, there should be installed a series of stations equipped with modern seismographs for the regis-

[49] In a late number of the *Popular Science Monthly* (February, 1909) the writer has pointed out the exceptional opportunities which the recent Messina disaster has offered for study by this method.

tration of the distant as well as the nearer and local earthquakes. These stations should be well distributed over the national domain, and should include a number of stations of the first rank provided with the more sensitive type of pendulum adapted to the registration of distant earthquakes. A larger number of stations of lower rank should be provided with simpler instruments suited only for securing full data upon the local shocks. These smaller stations should be located with due regard to the more important seismic provinces of the country. The United States Weather Bureau already possesses suitable buildings for installing such apparatus, and the regular employees of the stations could be trained to add the care of the instruments to their other duties. In 1907 with the hearty approval of the heads of the various scientific bureaus of the government, the American Association for the Advancement of Science, upon recommendation of its Committee on Seismology, memorialized Congress upon the pressing need of such a service. A year later, the Geological Society of America passed a resolution of similar import, and in the same year, no positive result having been secured, the Committee on Seismology renewed its first memorial by a second resolution.[49a]

Scientific research has already gone far to remove some of the greatest scourges of human existence. Of those which are characterized by sudden and usually unexpected visitation, are pestilence, flood, conflagration, earthquake and volcanic eruption. Of these flood and conflagration must be in part laid at the door of earthquake disturbances, to which they have all too frequently been an almost inevitable sequel. They have, moreover, taken the larger toll of human life and property. As compared with epidemic diseases, like the plague and smallpox which repeatedly overran Europe during the middle ages, earthquakes and their consequences have been the less destructive of life. It has been estimated that in Europe, the plague alone carried off no less than 25,000,000 people. Yet medical science has discovered the mystery of the disease, and in sanitation and isolation provided the remedy. To meet the great dangers of conflagrations, which from time to time

[49a] See also the resolution passed by the American Philosophical Society on April 24, 1909. *Proceedings* No. 191, p. xii.

have swept over our cities, we have as yet made only partial provision, yet the remedy is known and the country does not hesitate to make an annual expenditure conservatively estimated at $25,000,000, and in addition compels its citizens to build according to approved regulations.

A single earthquake has involved us in a loss of over $350,000,000, or nearly ten times the loss from the Baltimore fire.[50] Yet the government has expended nothing in an attempt to safeguard the future by avoiding the recurrence of such disasters. In Europe within a few months an entire city has been laid in ruins with a loss of life which may reach 150,000, yet the latest information makes it almost certain that this quake was not an exceptionally heavy one, and that most of the loss of life and property might have been avoided if proper methods of construction had been adopted.

It can hardly be claimed that the comparatively recent California disaster gave us our first warning of danger, for twenty years earlier the earthquake in South Carolina caused a loss of over one hundred lives, and property to the value of between $5,000,000 and $6,000,000. The earlier earthquakes within our territory have been far heavier and the small loss of life and property is accounted for only because the districts were at the time so thinly populated. We must not, therefore, overlook the fact that the United States is an earthquake country, and this not alone in its Pacific section. Some of our largest and most prosperous cities are almost certain to pass through their trials in the future, as Charleston and San Francisco have so recently. On February 5, 1663, almost the entire valley of the St. Lawrence and large sections of New England were visited by an earthquake, which, if the country had been built up as it is today, would have caused a disaster which it is not pleasant to contemplate.

Preparation of Maps of Fracture Systems.—As we have seen, earthquakes register the movement of portions of the earth's crust between planes of fracture. In just how far these fracture planes are present in advance of the movement, and in how far they result

[50] The official figures kindly furnished by Professor J. W. Glover.

from the relief of strain at the time of the shocks, has not yet been determined. Some writers have dismissed from consideration as "secondary phenomena" most of those visible fractures which first appear at the surface during an earthquake. It seems certain, however, that many of these fractures, at least, as regards both direction and position, are dependent upon the fracture system already present in the underlying rocks; and there is, therefore, need for extended study of the fracture and fault system within the rock basement of each earthquake province. With this study might perhaps be combined the determination of the depth and the earthquake properties of each of the overlying unconsolidated deposits. Experiments are further necessary in order to determine whether large thicknesses of such deposits are controlled by the same laws as are the thinner ones.

In every district which has an earthquake history, this record should be examined to learn if possible the points, the lines, or the areas of heaviest shock. Whenever data are sufficiently complete, maps should be compared to represent the approximate distribution of surface intensity for each earthquake, and comparisons instituted.

Maps of Visible Faults and Fissures and of Block Movements for Special Earthquakes.—It has been pointed out that in the case of a single earthquake only has a map been prepared to show in detail the distribution of the surface faults and the block movements of the ground. Thirty-five years after the event which brought them into existence, these faults have been mapped in detail by Mr. W. D. Johnson, of the United States Geological Survey. It has been possible to prepare maps of portions only of the district affected, and the full results are not yet published. Within the national damain there are at least two other provinces which promise fruitful results from such a study. These are the regions affected by the Sonora earthquake of 1887, and, even more important, the country about Yakutat Bay, Alaska, so profoundly modified in its relief during the earthquakes of 1899. A scientific party with headquarters upon a surveying vessel, such as we have described, would here find almost unequaled opportunities for securing important data.

Rate of Mountain or Shore Elevation by Quantitative Methods.

Wave-cut terrace and sea arch 10 feet above present sea level on coast of California. (After Fairbanks.)

Elevated shore line exhibiting stacks on coast of California near Port Harford. (After Fairbanks.)

—The studies of earthquakes during the last few years have done much to destroy the illusions of more than half a century. Since the time of Lyell, the burden of all geological instruction has been the extreme slowness of terrestrial dynamic processes. Oscillations of level described as slow and uniform warpings of the crust, had been gauged by measurement upon shores, which in the expressive language of de Montessus are dead, and where in consequence earthquakes are seldom or never left. If movements accomplished within a week and largely upon a single day, can elevate stretches of coast over 47 feet, as was true of portions of the Alaskan coast in 1899, what modifications of our traditional theories will be required! There is a pressing need for extended studies on rising coasts to determine by some scale the rate of elevation.

Now it happens that one of the most rapid of erosional processes is that accomplished by the waves as they beat upon a lee shore, and this process is one capable of fairly accurate quantitative measurement. The Pacific coast of North and South America, the greater part of the way from Alaska to Patagonia, has, during a recent period, been rising to the accompaniment of earth shocks. As we now understand, these uplifts have been mainly spasmodic, and the strand-lines abandoned with each successive uplift now stand revealed in a series of steps or terraces, which, when closely examined, reveal the characteristic marks of wave action sometimes at heights of fifteen hundred feet and more (see Fig. 7, and Plates XV. and XVI.). Careful maps prepared after correlation of these strand lines throughout long distances when combined with precise studies of the rate of wave cutting, could hardly fail to shed light upon the broader problems of seismic geology.

In some cases such abandoned shores now in an elevated position reveal clearly that their uplift was sudden and that no interval long enough to permit wave cutting separated it from the inauguration of the present level. Thus in figures 6 and 8 are represented shores which might almost be described as fossilized earthquakes, for the evidence is clear that the elevation took place in what was essentially a single sudden stage and must have been accompanied by a great quake.

Seacoasts offer the best possible data for observation and meas-

urement of the rate of uplift, because the level of the water can be made use of for the zero point. There are, however, other available means for investigating the rate of continental uplift. In arid and semi-arid regions, such as the Great Basin of the United States, the

FIG. 7. Elevated shore on the coast of California showing marks of wave action. (After Fairbanks.)

rare but violent storms cause torrents in the streams which debouch upon the plains from the mountain fronts, and so broad fans and aprons are there built up. Now if the uplift of the range goes on more slowly than the alluviation along its borders, the mountain front deposits will bury and hide the escarpments which are opened at the time of each successive uplift. If, on the other hand, the

uplift is the more rapid, fault scarps will appear cutting the unconsolidated deposits. Such scarps, some of them twenty feet in height, are characteristic of both the Eastern and the Western margins of

FIG. 8. Elevated and present shore lines registered in notches of chalk cliff at Cape Ciro, Celebes. (After Paul and Fritz Sarasin.)

the Great Basin region. From careful study of the rate of deposition there is here the possibility of reaching an approximate measure of the rate of uplift.

Investigation of Earthquake Water Waves.—The great water wave which followed the famous Lisbon earthquake of 1755 was

more destructive to human life than the shocks which proceeded it. The earthquake water wave which inundated the shore of Japan on June 15, 1896, destroyed human lives to the number of 29,953. Such waves have been especially destructive along the western coast of South America. The new seismology, by instrumental methods, points more and more definitely to the cause of such disturbances in the subsidence of great sections of the neighboring ocean floor; yet with the exception of relatively small waves within the Mediterranean, we are without observational data in the form of soundings in confirmation of this hypothesis. The bottom of the ocean is each year being charted in new areas, and we are fast accumulating data on which to base a decisive series of observations to settle this important question. This will certainly be one of the larger problems for investigation in seismic geology.

Conclusion.—It has been possible to indicate a few only of those directions along which effort will be directed in the early future of seismic geology. From this summary, I think it will be seen that there remain no other fields of investigation so long neglected and yet so full of promise in important discoveries, which are likely to touch so intimately the lives and happiness of human beings. What we have already learned is much of it as yet only half learned, and we need careful experimentation on lines already marked out, so that recommendations may be made for adapting our lives to future seismic conditions. Probably nine tenths of the danger from earthquakes can be avoided through practical methods of construction, but the relative cost of the different means of securing immunity must be carefully considered. The studies which are necessary are on such a scale that they call for generous government support, and it cannot be too strongly urged that the United States government undertake a work so clearly demanded by the situation. This support should be nothing less than the foundation of a bureau for earthquake investigation, with regular appropriations sufficient to carry out studies by a system of correlated earthquake stations, and also upon the ground of each devastated region whether it be at home or abroad.

University of Michigan,
April 21, 1909.

SEISMOLOGICAL NOTES.

BY HARRY FIELDING REID.

(*Read April 24, 1909.*)

(a) CONDITIONS PRECEDING AND LEADING TO TECTONIC EARTHQUAKES.

There are two classes of earthquakes: Volcanic and Tectonic; the former, connected with volcanic outbursts, seem to be due to explosions or to the sudden liberation of steam; the latter are due to ruptures of the rock. It is only the latter class that we shall consider at present.

Rock, like all solids, is elastic, and when subjected to external forces it suffers an elastic strain; if this strain is too great for the strength of the rock to withstand a rupture occurs; but it is never possible for a rupture to take place until the rock has been deformed or stretched beyond its elastic limit. When the rupture occurs, the two sides spring apart under the elastic forces and come to positions of equilibrium, free of elastic strains. The following experiments have been made to illustrate these conditions. Two short pieces of wood were connected by a sheet of stiff jelly 1 cm. thick, 4 cm. wide and about 6 cm. long, as shown in Fig. 1. The jelly was cut through along the line, tt', by a sharp knife and a straight line, AC, was drawn in ink on its surface. The left piece of wood was then shifted about 1 cm. in the direction of t', and a gentle pressure was applied to prevent the jelly from slipping on the cut surface. The jelly was sheared elastically and the line took the position AC shown in Fig. 2. On relieving the pressure so that the friction was no longer sufficient to keep the jelly strained, the two sides slipped along the surface tt' and the line AC broke into the two parts AE and DC. At the time of the slip A and C remained stationary, and the amount of the slip, DE, equalled the shift which A had originally experienced. A straight line, $A'C'$, was drawn on the jelly after the left side had been shifted, but before the jelly slipped along tt'. At the

time of the slip, the same movement took place in the neighborhood of this line, as near *AC*, and *A'C'* was broken into two parts, *A'E'* and *D'C'*; the total slip, *D'E'*, being equal to *DE*. A third experiment was tried; the left piece of wood was shifted 1 cm. and a straight line was drawn across it; it was then shifted a half centimeter more and the straight line took the position *A"C"* in Fig. 3. When the jelly slipped along the surface, *tt'*, the line broke into the

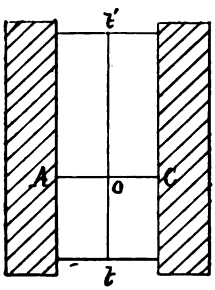

FIG. 1.

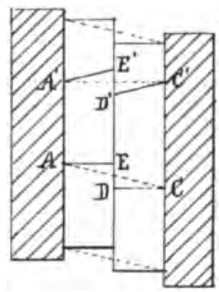

FIG. 2.

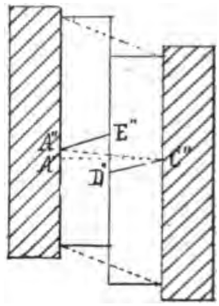

FIG. 3.

two parts, *A"E"* and *D"C"*; the slip, *D"E"*, being equal to the total displacement of the left side. Two characteristics of the movement are to be noted; the total slip on the ruptured surface equalled the total relative displacement of the blocks of wood; and, at the time of the slip the blocks remain stationary, and the whole movement at that time was an elastic rebound of the jelly to a condition of no strain.

These experiments illustrate as well as simple experiments could what occurred at the time of the California earthquake of April 18, 1906. Fortunately, early surveys had been made of this region which Dr. Hayford, in the report of the California Earthquake Commission has, for the sake of discussion, divided into two groups; I., the surveys made from 1851–65; II., those from 1874–92. A third survey (III.) was made after the earthquake in 1906–7. These surveys extended from Mt. Diablo, about 33 miles east of the fault, to Farallon Light House, about 22 miles west of it. They showed that between the I. and II. surveys Farallon Light House had shifted relatively to Mt. Diablo, 4.6 feet north-northwest, practically in a direction parallel with the fault-line; and between II. and III. sur-

veys it had shifted 5.8 feet more in nearly the same direction, making a total shift in about 50 years of 10.4 feet.

Observations in the field on the offsets of fences and roads showed that at the time of the earthquake there was a relative movement of the two sides at the fault-surface, amounting to something like 20 feet, and it is only reasonable to suppose that this movement was equally divided between the opposite sides of the fault. The surveys show that the actual displacement which took place between II. and III. diminished as the distance from the fault became greater; on the east side the displacement practically died out at a distance of four or five miles from the fault, and on the west side the displacement became equal to that of Farallon Light House at about the same distance from the fault. All the phenomena were in close accord with the experiments described above. The main difference consists in the fact that a straight line on the earth's surface across the fault and at right angles to it did not break up into two straight lines, as in the experiment, but into two curved lines. We ascribe this curvature to the fact that the forces which produced the displacement of the ground were applied below the crust of the earth, whereas in the experiment they were applied at the outer boundary of the jelly.

The elastic rebound near the fault-surface, of course, took place suddenly at the time of the earthquake; and the surveys show that between I. and II., and between II. and III. there was a relative shift of very extensive regions on opposite sides of the fault, but the surveys do not determine whether these shifts took place suddenly at the times of the great earthquakes of 1868 and 1906, or whether they were the effect of a slow, gradual movement continuing through the years. We must turn to other considerations to decide this point. In the experiments we have described the elastic rebound was greatest at the ruptured surface, became progressively less at greater distances from this surface, and the jelly in contact with the wooden blocks did not partake of the movement at all. The experiments might have been varied and instead of a slow shift of the block gradually setting up an elastic shear, we might have set up the shear suddenly; but this was not

necessary to produce the phenomena which we know took place at the time of the earthquake. It seems impossible to think that the general shift was sudden; for we cannot imagine what forces could have produced a sudden displacement, amounting to four or five feet, of a portion of the earth's surface covering thousands of square miles. But we have indubitable evidence, in the foldings of the rock common to all mountain chains, of the slow displacement of large regions to considerable distances; and unless such a displacement were slow enough to allow the rock everywhere to flow viscously and thus adjust itself to its new position, there would be places where the elastic stresses would from time to time be greater than the strength of the rock and ruptures would occur causing earthquakes.

This view of the case is so entirely in accord with the elastic properties of rock, and with the slow movements of large regions, familiar to geologists, that it commends itself strongly without further argument; but there is a consideration which seems almost decisive in its favor. In the experiments described we saw that the relative slip at the ruptured surface was exactly equal to the total relative shift of the wooden blocks; this, of course, was independent of the slow or sudden nature of the shift. The slip on the fault-surface at the time of the California earthquake was about 20 feet; therefore the shift of the more distant regions which brought about the break must have been as great; but the surveys show that between II. and III., the shift was only 5.8 feet, and between I. and II., 4.6 feet; that is, in all, only about 10.4 feet since the earliest surveys, some 50 years before the shock. We can therefore say, definitely, that the shift which set up the elastic strains which finally resulted in the earthquake, not only did not wholly take place at the time of the rupture but that even fifty years earlier it had already accumulated to about one half its final amount; that between the I. and II. surveys it increased to about three-quarters of this amount, and that the last quarter was added between the II. and III. surveys. It is hardly possible, in view of this history not to be convinced that the shift accumulated gradually.

Since the general order of events, that is, the setting up of elastic strains resulting in the rupture of the rocks which preceded

and caused the California earthquake, were the consequences not of special conditions but of the general properties of rock, we may make the general statement that *tectonic earthquakes are caused by the gradual relative displacement of neighboring regions, ~~which~~ sets up elastic strains so great that the rock is ruptured; and that at the time of the rupture no displacements of large areas take place, but there occurs merely an elastic rebound, to an unstrained position, of the lips of the fault extending but a few miles on each side of it.*

It is not necessary of course that the slow displacement should set up a simple horizontal shear, as in the case of the California earthquake, but simply that an elastic strain of some kind should be produced by the relative displacement of adjoining regions. This may be due, for instance, to the slow sinking of a large region with the production of vertical elastic shears around its boundary, and when these shears become sufficiently strong a break will occur and the movement of the two lips will be vertical and in opposite directions, thus producing a fault-scarp. The main, sinking region, however, would not suddenly drop at the time of the break; there would only be an elastic rebound around its boundaries; its own displacement having taken place slowly over a long period of time. The elastic strains might also be set up by a horizontal compression, in which case the rock would be folded upward, and when the curvature became too great it would break like a bent stick, both sides of the broken surface flying upwards under the elastic forces and leaving an open fissure between them. Examples of this kind of rupture are only known on a small scale.

It is possible that the rupture may not be confined to a single surface, but may be distributed over a number of neighboring surfaces, and a small block between these surfaces may be displaced as a whole; but this must be looked upon as a minor phenomenon of the fault-zone, and is not an example of the readjustment of large blocks.

(*b*) Some Characteristics of Seismological Instruments.

When efforts began to be made, some thirty or forty years ago, to produce an instrument that would record the actual movement of the ground caused by an earthquake, the object aimed at was to

produce a "steady mass," that is, a heavy mass that would remain at rest in spite of the movement of its support; and by recording, either directly or through magnifying levers, its movement relative to the ground, the hope was entertained that the actual movement of the ground would be obtained. But the hope was futile. Every seismograph consists essentially of two parts: a heavy mass adjusted in a greater or less degree to a condition of neutral equilibrium, and the drum or other surface on which the record is made. If the mass could be adjusted absolutely to neutral equilibrium and could be kept in that condition in spite of the movement of its support, it would remain at rest, and would record the true movement of the earth; but the size of the recording apparatus is limited and in order that the record should be made on it, the heavy mass must remain pretty closely in one position, which is practically incompatible with neutral equilibrium. It was found necessary to keep the mass in stable equilibrium although the force brought into play by a small displacement might be very small. If displaced the mass would, therefore, vibrate about its position of equilibrium with a period of its own; and the record of every earthquake is the combination of the earth's movement with that of the heavy mass; and if the period of the vibrations of the earth happens to approach that of the heavy mass, the amplitude of the latter increases greatly, and indicates a movement of the earth much larger than actually occurs. We cannot deduce the movement of the earth from the record except by a careful analysis based on the mathematical theory of the seismograph. This, fortunately, has been worked out; but, unfortunately, it is rather complicated, and it is only in comparatively simple cases that it can be applied without very great labor.

The earlier investigators also thought that all solid friction or viscous damping reduced the sensitiveness of the instrument, and that a long period of vibration increased it. Solid friction is indeed always harmful and should be reduced as much as possible, but viscous damping is a great advantage and simplifies the interpretation of the record. Remembering that every earthquake consists of vibrations of many periods, a glance at figure 4 will show the great benefit of strong damping. The curves show the magnifying power of the seismograph so far as it depends upon the ratio of the

period of the earth's vibration to that of the seismograph itself, and upon the viscous damping. The damping ratio is the ratio of the amplitude of successive swings of the heavy mass, when it is

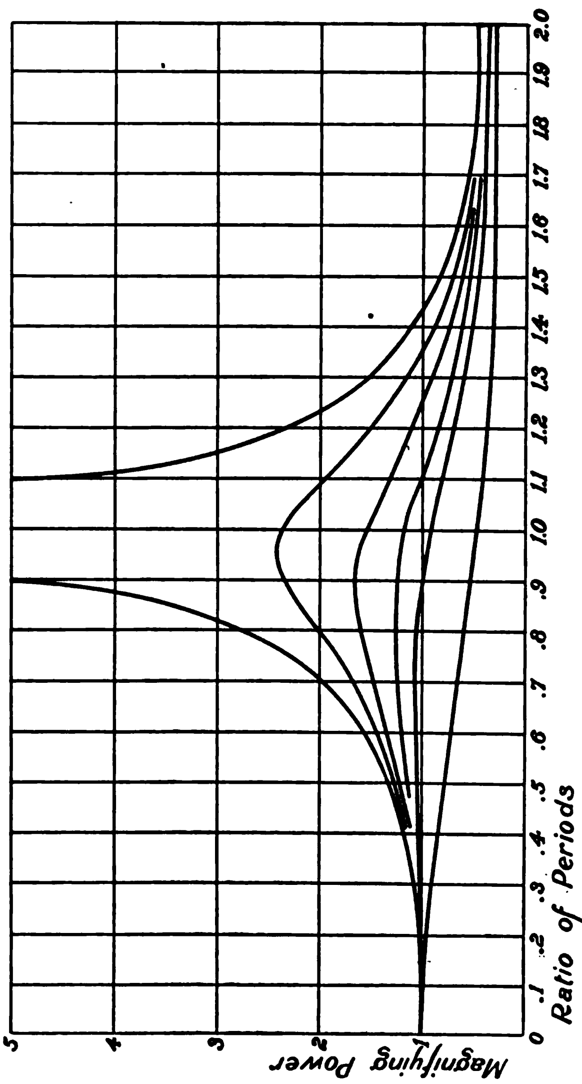

FIG. 4.

allowed to swing freely. If this ratio is nearly 1 : 1, that is, if there is very little damping and the amplitude of the swinging mass dies

down very slowly, the curves show that the magnifying power for vibrations of very short period is unity; that is, the record gives the true amplitude of the earth's motion; for vibrations of longer period the magnifying power rapidly increases, and when the ratio of the periods is unity; that is, when the period of the earth's motion and the free period of the seismograph are equal, the magnifying power becomes extremely large. For still longer periods the magnifying power again decreases and when the period becomes very long, it becomes extremely small. Since, therefore, the vibrations of various periods are differently magnified, it is quite evident that the record of an earthquake would be greatly distorted, some vibrations being unduly emphasized, and others unduly minimized. It is just in this respect that damping is beneficial. Within limits, the inequality of magnifying power for various periods becomes less as the damping ratio becomes greater; and when the damping is great enough to reduce the relative amplitude of successive swings in the ratio of 8:1, the magnifying power is nearly uniform for all periods less than that of the seismograph. A seismograph, damped to this amount, and with a period as long as the longest of those present in the earth's vibrations, would give a much truer representation of the earth's movement.

The advantage of a long free period is not to increase the sensitiveness of the seismograph but to increase the range of periods over which its sensitiveness may be maintained. Contrary to a very general belief, the magnifying power for vibrations of very short periods is not affected by the amount of damping.

(*c*) Suggestions for a National Seismological Bureau.

The work of collecting information regarding earthquakes, and studying this material is so extensive that it cannot be carried out thoroughly except with the aid of the federal government. The United States is almost the only country of importance which does not give governmental aid to the study of earthquakes; and, although, fortunately, the larger part of this country is only subject to occasional slight shocks, extremely destructive shocks have occurred within our boundaries, and certain districts are frequently visited by earthquakes which cause much damage. The study of earth-

quakes is a thoroughly practical subject, and if properly prosecuted, will be of distinct benefit to the country.

Let us glance, for a moment, at the special problems which a national bureau should take up. They may be enumerated as follows:

1. The collection of information regarding earthquakes in the United States and its possessions.

2. The study of the distribution of earthquakes in the United States and the preparation of maps showing this distribution and its relation to the geological structure.

3. The study of special regions, such as the California coast.

4. The prompt examination of a region which has suffered a severe earthquake.

5. The collection of information regarding earthquakes under the sea, and tidal waves.

6. The study of the earthquakes of the Gulf of Mexico and the Caribbean Sea from the records of instruments around these areas.

7. The issue of monthly bulletins, giving the records of felt earthquakes and of seismographs in the United States.

8. The study and dissemination of information regarding the best methods of construction in areas subject to earthquakes.

9. The theoretical study of earthquake instruments.

10. Other theoretical studies.

The variety of these studies requires the sympathetic cooperation of many branches of the government for their successful prosecution. The Weather Bureau and the Post Office Department are especially adapted to collect information regarding felt earthquakes; and the trained observers of the former, distributed as they are all over the country, could readily add a seismograph to the instruments under their charge and obtain important records of distant and near earthquakes. The Navy, through its personnel and through its Hydrographic Office has especial facilities for collecting information regarding earthquakes felt at sea. The Geological Survey alone could study the relation of geological structure to the occurrence of earthquakes; and the Coast and Geodetic Survey has on its staff able mathematicians capable of deducing the characteristics of the interior of the earth from the velocity of earthquake waves through

it, and of finding the answer to the question whether earthquakes produce changes in the earth's magnetism.

In looking over the history of the various scientific bureaus of the government, we see that they were, in general, started by the Smithsonian Institution, and after their work had been thoroughly marked out and justified, they became independent. It seems not only conservative, but most practical, to follow this precedent in the establishment of a seismological bureau; for the Smithsonian is excellently adapted for prosecuting earthquake studies, and it could probably secure the hearty cooperation of all the other departments of the government more easily than could any single one of these departments.

SOME BURIAL CUSTOMS OF THE AUSTRALIAN ABORIGINES.

By R. H. MATHEWS, L.S.

(*Read May 21, 1909.*)

Oval-shaped objects used in connection with native burials in the valley of the Darling River, New South Wales, were manufactured from burnt gypsum,[1] reduced to a powder, and fine sand or ashes, well compounded with water, just as we would mould anything of the kind out of cement or plaster of paris. The necessary shape could be given to the mass while plastic and then allowing it to dry in the sun. These objects are in the shape of a large egg, varying in length from about three to nine inches, by a width of say two and a quarter inches for the smaller ones, up to double that width for the larger. (See Figs. 1, 2, 3 and 4, page 314.)

They are often approximately circular in a section through the middle part, but in other cases such a section would be ovate. Some of them are flattish on one or both sides and are not unlike a cake baked in an elongated form. In a few of the flattened productions, one side is slightly concave, but whether this was intended by the maker it is difficult to say. Probably the wet mass assumed this shape when drying in the sun, because the heat would naturally cause the outer margin, which would dry first, to turn upward, similarly to the way a board warps toward the sun, when exposed in a free state. Nearly all the specimens I have seen were evidently manufactured in the way above described, but an occasional one consists of a piece of sandstone or shale, of a light color, found in the bush, which required but little fashioning to bring it to the required shape.

An old aboriginal, of the Ngunnhalgu tribe, known as Harry Perry by the white people, told me that these *kopai* objects, which he

[1] Called *kopai* by the natives; often erroneously written *copi* and *kopi* by the European residents of that region.

called *mūrndu,* were made out of powdered kopai and a little sand or ashes, much in the way we mix up flour when making dough for baking into bread. He said that when a native of either sex died and was buried, the relatives came to the grave and placed these

1 2 3 4

This picture shows three medium sized cakes and one small one, all of which are made from gypsum (*kopai*), as above described. I shall call them *murndu,* their native name in the Ngunnhalgu tribe, which occupied the country from about Wilcannia up to near Louth, being the tract from various parts of which my specimens were obtained.

Fig. 1. The *murndu* numbered 1 in the picture, is 6¾ inches long, by a maximum width of 4¾ inches. The thickest part, at right angles to the width, is 3⅞ inches. The weight of the article is 2 lbs. 9 oz.

Fig. 2 measures 2¾ inches in length, by a mean thickness of 2⅛ inches. Weight, 4½ oz.

Fig. 3 has a length of a little over 7⅞ inches and its greatest breadth is 4⅛ inches. It is oval in section, with a thickness of 3¼ inches. Weight, 2 lbs. 14 oz.

Fig. 4 is 6 9/16 inches in length, with a maximum breadth of 3 15/16 inches. It has a practically circular section through the middle. Weight, 2 lbs. 8 oz.

Scattered here and there through the composition of the balls are pieces of gypsum as large as gravel, showing that the mineral was not very well pulverized; a fact which does not surprise us, when we remember that the natives had to burn the gypsum in a camp fire. For the same reason the powder became mixed with small quantities of wood ashes.

kopai balls on top of the mound of earth. For example, if the body were that of an adult man, his widow would place a *mūrndu* on the ground above his head. The deceased's brothers would each place one or more along one side of the grave; his mother and sisters might also lay a *mūrndu* or two on the other side; and so on.

An old man of the Murawarri tribe informed me that in his language the *kopai* ball or tablet is called *yūrda.* When a man, woman, or young person beyond the age of childhood, died, leaves were strewn over the earth covering the grave, and on top of the leaves were laid the *yūrda.* There might be only one or two *yūrda* deposited, or there might be more, depending upon whether the deceased had few or many friends. Mr. E. J. Suttor tells me that he has seen a dozen or more of these kopai balls lying on a native's grave. They were put on as soon as the corpse was buried.

A Ngēumba blackfellow told me that in his tribe the name of the *kopai* balls is *dhaura.* The gypsum was collected, burnt and pounded fine by the women, and the men shaped the *dhaura.*

A resident informs me that gypsum is very plentiful on Yantara Station, near Lake Cobham, about 120 miles northwesterly from the Darling River, where tons of it could easily be obtained. Another correspondent, at Kallara Station on the Darling, states that gypsum is quite plentiful there. In fact, gypsum and pipeclay are both easily obtainable along the valley of the Darling, as well as in the hinterland, all the way from its junction with the Murray River up to Brewarrina. There is also a kind of slacked or rotted gypsum which occurs in patches, resembling slacked lime.

Old Perry and others above quoted said that the object of decorating the grave in the way described was to induce the *bo-ri* or spirit of the dead person, to remain in its place of sepulture and thus prevent its roaming through the camp at night to do injury to anyone with whom the deceased might in his or her lifetime have had a feud. When the spirit saw that its owner's death had been properly mourned for in accordance with the tribal custom, it felt more friendly towards everybody. The spirit comes up during the night and sits on top of the grave and commences licking or sucking one or more of the kopai balls.

Sir Thomas L. Mitchell is the first author to mention these *kopai* balls. He says:

> It was on the summit of a sandhill where I fixed my depot on the Darling [Fort Bourke] that we saw the numerous white balls, and so many graves. The balls are shaped as in the accompanying woodcut, and were made of lime. . . . A native explained one day to Mr. Larmer [a member of Sir

Thomas's Staff] in a very simple manner the meaning of the white balls, by taking a small piece of wood, laying it in the ground and covering it with earth. Then laying his head on one side and closing his eyes, he showed that a dead body was laid in that position in the earth, where these balls were placed above.[2]

In 1901, Mr. G. Officer, of Kallara Station, described some kopai balls or cakes found at a grave on Curronyalpa run on the Darling River, about fifteen miles above Tilpa. There were thirty-nine specimens at the grave, some of which were lying on the surface, others were partially revealed, and the remainder were found by digging a little way into the sandy soil underneath.

FIG. 5 is an exterior view of a *kurno* or widow's cap, *a* being the front, or part fitting over the forehead, whilst *b* represents the back of the head.

Owing to the unusually large number of pieces on this grave, I am inclined to believe that the greater portion of them had been carried from other graves in the neighborhood to this spot and hidden, for the purpose of protecting them from the vandalism of the white men, who were in the habit of carrying them away as curios. Mr. Higgins, a long resident of the Darling region, writes me that two old blackfellows had stated to him that, when the natives observed that the white people desecrated their burying places in this way, they themselves buried the kopai balls in the ground to keep them

[2] "Three Expeditions into Eastern Australia" (London, 1838), Vol. I., pp. 253-4. Seven *kopai* balls are illustrated in the woodcut referred to.

out of sight. Possibly nearly all the specimens recovered by Mr. Officer had originally been concealed with earth, but the violent winds of that district had blown the sandy soil away and left them visible. The grave was on a sandhill about three miles back from the river and was therefore out of the way of the white men, whose principal traffic lay along the course of the stream.

Helmet-shaped objects, called *kurno,* known to have been worn on the heads of widows as a sign of mourning, were made from gypsum, burnt and pounded fine, and mixed with water. A fiber

FIG. 6 shows the interior of the cap, with the marks or impression of the net, and the size of its meshes, plainly discernible. This cap weighs 11 lbs. 1 oz., and has been formed of *kopai* or gypsum in the way already described. The specimen was found on a native grave on Lower Budda run, Darling river. I am indebted to Mr. F. W. Beattie for the two photographs, which he took at my request.

or rush net was first placed on the woman's head to protect the hair, and the soft mixture applied outside until it resembled a cap, hence called "widow's caps" by the Europeans. The mixture was not all put on at the same time but by a series of additions extending over a few weeks. The marks of the meshes of the net are distinctly visible in the interior of some of the "caps" of this kind which have been preserved by white men. When the mourning cap had been worn

the customary time, it was taken off and placed by the widow upon the grave of her late husband. When the deceased left a plurality of widows, each wore an emblem of mourning and disposed of it in the same way. If the net was firmly embedded in the dried gypsum, it was left in it, but if the net could be readily detached it was taken out of the cap for future use. In some cases, portions of the woman's hair had to be cut to get the cap off. If the net was left in the cap, it rotted away, but its impression remained. (See Figs. 5 and 6, pages 316 and 317.)

Sir Thomas L. Mitchell reports that on the Darling River he found "Casts in lime or gypsum, which had evidently been taken from a head, the hair of which had been confined by a net, as the impression of it, and some hairs, remained inside." The same author states that, on the Murray, some distance above its confluence with the Darling, he saw some native graves with mounds of earth raised over them, on which were laid the "singular casts of the head in white plaster" which he had before seen at Fort Burke. In some cases the casts of the head were found lying beside the gypsum balls. He gives illustrations of these two "casts," showing also the marks of the net inside.[3]

In 1838, Mr. Joseph Hawdon observed some skull-shaped caps, made of white plaster, which he thought was obtained by burning shells and grinding them into powder. They were laid on the grave of a native near Lake Bonnie on the Murray River. He says that inside the cap was a network of twine. Mr. Hawdon states that he also noticed a great quantity of crystallized lime or gypsum in the locality; it was in masses some tons weight.[4]

Mr. E. J. Eyre gives an example of the "Korno, or widow's mourning cap, made of carbonate of lime, moulded to the head." The specimen illustrated by him weighed 8½ lbs.[5]

[3] *Op. cit.*, Vol. I., pp. 253–254, and Vol. II., p. 113.

[4] "Diary of an Overland Journey from Port Phillip to Adelaide in 1838" (MSS).

[5] "Journs. Expeds. Discov. Cent. Australia" (London, 1845), Vol. II., p. 509, Plate I., Fig. 17.

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HELD AT PHILADELPHIA

FOR PROMOTING USEFUL KNOWLEDGE

VOL. XLVIII. SEPTEMBER–DECEMBER, 1909. NO. 193.

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American Philosophical Society

General Meeting—April 21-23, 1910

The General Meeting of 1910 will be held on April 21st to 23rd, beginning at 2 p. m. on Thursday, April 21st.

Members desiring to present papers, either for themselves or others, are requested to send to the Secretaries, at as early a date as practicable, and not later than March 19, 1910, the titles of these papers, so that they may be announced on the programme which will be issued immediately thereafter, and which will give in detail the arrangements for the meeting.

Papers in any department of science come within the scope of the Society, which, as its name indicates, embraces the whole field of useful knowledge.

The Publication Committee, under the rules of the Society, will arrange for the immediate publication of the papers presented.

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Secretaries.

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THE AMERICAN-BRITISH ATLANTIC FISHERIES QUESTION.

BY THOMAS WILLING BALCH.

(*Read April 22, 1909.*)

When the thirteen original colonies and the mother land closed in 1783 by the Treaty of Paris the civil war that had raged between them since 1775, and the United States were recognized by Great Britain as a member of the family of nations, both parties thought that, by that treaty of partition of 1783, they had arranged all the differences then existing between them. But during the century and a quarter that has elapsed since the Treaty of Paris was signed, the United States and Great Britain have been engaged in endless discussions and arguments concerning the proper interpretation of that treaty. Among these mooted questions, that of the Atlantic fisheries has been a fruitful bone of contention between the two leading Anglo-Saxon powers. At length, just as so many other points of difference between these two nations have been settled in peace by a reference to international arbitration, so this question of the Atlantic fisheries is to be so arranged by referring it to the decision of The Hague International Court. This sensible and humane agreement of two great powers to refer the solution of this question to that august tribunal instead of allowing it to become a cause of war, will be another " mile stone " in the evolution of inter-

national arbitration. In the following paper, I have briefly considered this important and live question.

Great Britain and her North American colonies shared in the burdens and anxieties of the struggle that resulted in the overthrow of the French power in North America, and after the cession of Canada and the French maritime provinces around the Gulf of Saint Lawrence to the British Empire in 1763, the motherland of England and the British North American colonies had in common a large heritage in northeastern America. And the fishermen of the northeastern colonies resorted to the Gulf of Saint Lawrence and adjacent waters to catch their share of the rich harvest of fish that was to be found in those waters.[1]

During the negotiations for peace at Paris in 1782 between the motherland and her revolted colonies, one of the subjects that gave much cause of trouble to the negotiators was the right to participate in the fisheries. On November 25, 1782, the British commissioners proposed to the American negotiators that the citizens of the United States should have the liberty of taking fish of every kind in all the waters of the Gulf of Saint Lawrence and on all the Newfoundland banks, and to dry and cure fish on the shores of the Isle of Sables and of the Magdalen Islands in the Gulf of Saint Lawrence, so long as those coasts remained unsettled, on "condition that the citizens of the United States do not exercise the fishery but at the distance of three leagues from all the coasts belonging to Great Britain, as well those of the continent as those of the islands situated in the Gulf of Saint Lawrence. And as to what relates to the fishery on the coast of the island of Cape Breton out of the said gulf, the citizens of the said United States shall not be permitted to exercise the said fishery but at the distance of fifteen leagues from the coasts of the island of Cape Breton."[2]

By this proposition not only were American citizens prevented

[1] Sir George Otto Trevelyan, "The American Revolution," New York, 1899, Part I., pp. 263, 264.

[2] Francis Wharton, "The Revolutionary Diplomatic Correspondence of the United States," Washington, 1889, Vol. VI., pp. 74–76.

from drying fish on the shores of Nova Scotia, but also to catch fish within three leagues of the shores around the Gulf of Saint Lawrence and within fifteen leagues of the shores of Cape Breton Island on its seaward side. Thus by this last provision the British envoys wished to close to American citizens the right to fish in a part of the high seas that were then recognized as a joint possession of all mankind. These proposals were promptly rejected by the American commissioners, and on November 28, John Adams, for the latter, submitted a counter plan.[3] Further parleys were held on this important question. As the Americans contended firmly for the rights of their citizens to fish on the Newfoundland banks, and Adams said he would not sign any agreement that did not secure to the American fishermen the right to catch fish in the Newfoundland and adjacent waters, the British commissioners yielded the point.[4] After numerous propositions and changes, the contending negotiators at length agreed on the following article that was embodied in the treaty of peace finally signed in 1783.[5]

Article III. It is agreed that the people of the United States shall continue to enjoy unmolested the right to take fish of every kind on the Grand Bank, and on all the other banks of Newfoundland; also in the Gulph of St. Lawrence, and at all other places in the sea, where the inhabitants of both countries used at any time heretofore to fish. And also that the inhabitants of the United States shall have liberty to take fish of every kind on such part of the coast of Newfoundland as British fisherman shall use, (but not to dry or cure the same on that island;) and also on the coasts, bays and creeks of all other of his Britannic Majesty's dominions in America; and that the American fishermen shall have liberty to dry and cure fish in any of the unsettled bays, harbors and creeks of Nova Scotia, Magdalen Islands, and Labrador, so long as the same shall remain unsettled; but so soon as the same or either of them shall be settled, it shall not be lawful for the said fishermen to dry or cure fish at such settlements, without a previous agreement for that purpose with the inhabitants, proprietors or possessors of the ground.

Thus that treaty, that provided for a partition between the motherland and her North American colonies of the territory that they enjoyed in common, also provided for a partition in the en-

[3] Francis Wharton, "The Revolutionary Diplomatic Correspondence of the United States," Washington, 1889, Vol. VI., p. 85.

[4] Francis Wharton, "The Revolutionary Diplomatic Correspondence of the United States," Washington, 1889, pp. 86–87.

[5] "Treaties and Conventions concluded between the United States of America and other Powers since July 4, 1776," Washington, 1889, p. 377.

joyment of the "right" to reap the benefits of the rich fisheries around Newfoundland and in the adjoining waters that the subjects of the motherland and the colonies had won by their joint exertions and valor. And subject to the provisions of the treaty of peace as embodied in its third article, American fishermen continued to take fish in the waters around Newfoundland and the Gulf of Saint Lawrence as formerly they had fished in those same waters as British subjects.

When the American and the British negotiators met at Ghent in August, 1814, to agree upon a treaty of peace to put an end to the state of war existing between their respective countries, the British commissioners said, among other things, that

> They felt it incumbent upon them to declare that the British Government did not deny the right of the Americans to fish generally, or in the open seas; but that the privileges formerly granted by treaty to the United States of fishing within the limits of the British jurisdiction, and of landing and drying fish on the shores of the British territories, would not be renewed without an equivalent.[6]

A few days later the British commissioners also brought up the question of the free navigation for British subjects of the Mississippi River.[7] In the following November the American negotiators in submitting a project for a treaty to their British colleagues, said, in an accompanying note that they were "not authorized to bring into discussion any of the rights or liberties" that the United States had up to then enjoyed in the fisheries. After much sparring between the two groups of negotiators as to the fisheries, the navigation of the Mississippi and other points of difference, the two sides, who were both desirous of concluding peace, agreed to exclude altogether any mention of either the fisheries or the navigation of the Mississippi from the treaty of peace that they concluded at Ghent on December 24, 1814.[8]

The rights of American fishermen in the northeastern American

[6] "American State Papers: Class I., Foreign Relations," Washington, 1832, Vol. III., p. 705.

[7] John Quincy Adams, "The Duplicate Letters, The Fisheries and the Mississippi; Documents relating to transactions of the Negotiations of Ghent," Washington, 1822, pp. 54, 55, 184.

[8] "American State Papers: Class I., Foreign Relations," Washington, 1832, Vol. III., pp. 744, 745.

fisheries came to public notice a few months later. On June 19, 1815, the British sloop *Jaseur,* warned an American cod fishing vessel, when out in the open sea some forty-five miles from Cape Sable, not to approach within sixty miles of the coast. This act trenching on the rights of all mankind to fish in the open sea, the British government disowned.[9] Lord Bathurst, however, at the same time said to John Quincy Adams that while the British government "could not permit the vessels of the United States to fish within the creeks and close upon the shores of the British territories," it would not interfere with American fishermen "in fishing anywhere in the open sea, or without the territorial jurisdiction, a marine league from shore."[10]

The question of whether or not the third article of the American-British treaty of peace of 1783—whereby American fishermen were secured fishing rights in certain of the territorial waters of Britain in North America—was abrogated by the War of 1812, was during the next few months discussed by John Quincy Adams, American Minister to Great Britain, and Lord Bathurst, British Minister of Foreign Affairs. On September 25, 1815, Mr. Adams, in a communication addressed to the Earl of Bathurst, argued that the treaty of 1783 was "not, in its general provisions, one of those which, by the common understanding and usage of civilized nations, is or can be considered annulled by a subsequent war between the same parties."[11]

On October 30 following, Lord Bathurst replied to Mr. Adams at length. He said:[12]

> To a position of this novel nature Great Britain can not accede. She knows of no exception to the rule, that all treaties are put an end to by a subsequent war between the same parties. . . . The treaty of 1783, like many other, contained provisions of different characters—some in their own nature irrevocable, and others of a temporary nature. . . . The nature of the liberty

[9] "American State Papers: Class I., Foreign Relations," Washington, 1834, Vol. IV., p. 349.

[10] "American State Papers: Class I., Foreign Relations," Washington, 1834, p. 350.

[11] "American State Papers: Class I., Foreign Relations," Washington, 1834, p. 352.

[12] "American State Papers: Class I., Foreign Relations," Washington, 1834, pp. 354, 355.

to fish within British limits, or to use British territory, is essentially different from the right of independence, in all that may reasonably be supposed to regard its intended duration. . . . In the third article (of the treaty of 1783), Great Britain acknowledges the *right* of the United States to take fish on the banks of Newfoundland and other places, from which Great Britain has no right to exclude an independent nation. But they are to have the *liberty* to cure and dry them in certain unsettled places within His Majesty's territory. If these liberties, thus granted, were to be as perpetual and independent as the rights previously recognized, it is difficult to conceive that the plenipotentiaries of the United States would have admitted a variation of language so adapted to produce a different impression; and, above all, that they should have admitted so strange a restriction of a perpetual and indefeasible right as that with which the article concludes, which leaves a right so practical and so beneficial as this is admitted to be, dependent on the will of British subjects, in their character of inhabitants, proprietors, or possessors of the soil, to prohibit its exercise altogether. It is surely obvious that the word *right* is, throughout the treaty, used as applicable to what the United States were to enjoy, in virtue of a recognized independence; and the word *liberty* to what they were to enjoy, as concessions strictly dependent on the treaty itself.

On January 22, 1816, the American Minister addressed a reply to Lord Castlereagh, who had in the meantime succeeded Lord Bathurst as foreign secretary. He said the treaty of 1783 was intended to arrange the whole scope of the diplomatic relations between the two nations. He said the British note admitted that treaties often contained recognitions in the nature of continuing obligations; and that it admitted that the treaty of 1783 was such a treaty, except a small part of the article relating to the fisheries and the article about the navigation of the Mississippi.

In searching for the answer of International Law to this difference of opinion, two principal sources can be looked to—the judgments of courts of law and the opinions of leading international jurists. In the first class there are two judgments, one rendered by an American and the other by an English court, that sustain the American contention that the third article of the treaty of 1783 was not terminated by the War of 1812.

In the case of the " Society for the Propagation of the Gospel in Foreign Parts *vs.* The Town of Newhaven," the Supreme Court of the United States, in rendering judgment, was called upon to pass on the continuance or extinguishment of treaties, especially upon that of 1783, by a subsequent war. On March 12, 1823, Mr. Justice Wash-

ington,[13] delivered the opinion of the court. On the continuance of treaties, he held:[14]

But we are not inclined to admit the doctrine urged at bar, that treaties become extinguished, *ipso facto,* by war between the two governments, unless they should be revived by an express or implied renewal on the return of peace. Whatever may be the latitude of doctrine laid down by elementary writers on the Law of Nations, dealing in general terms on this subject, we are satisfied, that the doctrine contended for is not universally true. There may be treaties of such a nature, as to their object and import, as that war will put an end to them; but where treaties contemplate a permanent arrangement of territorial and other national rights, or which, in their terms, are meant to provide for the event of an intervening war, it would be against every principle of just interpretation to hold them extinguished by the event of war. If such were the law, even the treaty of 1783, so far as it fixed our limits, and acknowledged our independence, would be gone, and we should have had again to struggle for both upon original revolutionary principles. Such a construction was never asserted, and would be so monstrous as to supersede all reasoning.

We think, therefore, that treaties stipulating for permanent rights, and general arrangements, and professing to aim at perpetuity, and to deal with the case of war as well as of peace, do not cease on the occurrence of war, but are, at most, only suspended while it lasts; and unless they are waived by the parties, or new and repugnant stipulations are made, they revive in their operation at the return of peace.

In the case of "Sutton *vs.* Sutton," in order to decide the case at bar, it was necessary for the British High Court of Chancery to pass upon the continuance or abrogation of the treaty of 1794, between America and Britain, known as Jay's Treaty, after the War of 1812 between these two powers. Sir John Leach, Master of the Rolls in the British High Court of Chancery held:[15]

The relations, which subsisted between Great Britain and America, when they formed one empire, led to the introduction of the ninth section of the treaty of 1794, and made it highly reasonable that the subjects of the two parts of the divided empire should, notwithstanding the separation, be protected in the mutual enjoyment of their landed property; and, the privileges of natives being reciprocally given, not only to the actual possessors of lands but to their heirs and assigns, it is a reasonable construction that it was the intention of the treaty that the operation of the treaty should be permanent, and not depend upon the continuance of a state of peace.

[13] Mr. Justice Bushrod Washington.

[14] Wharton's "United States Supreme Court Reports," New York, 1823, p. 494.

[15] Russell and Mylne's "Chancery Court Reports," Vol. I., 676.

International publicists are not unanimous on the question whether war terminates all or every part of treaties. Formerly the weight of opinion held to the view that a state of war between two nations terminated the treaties between them *in toto*. To-day, however, the weight of opinion, in accordance with the trend of International Law towards the more humane goal of mitigating and lessening war, tends to the view that many treaties, either in their entirety or in part, are not abrogated by a state of war by the contracting states.

In support of the former or English view, there is Vattel, who says:[16]

Les conventions, les traités faits avec une Nation, sont rompus ou annullés par la guerre qui sélève entre les contractans; soit parce qu'ils supposent tacitement l'état de paix, soit parce que chacun pouvant dépouiller son ennemi de ce qui lui appartient, lui ôte les droits qu'il lui avoit donnés par des traités.

Phillimore, the English jurist, maintains almost the same view.[17]

Oppenheim, formerly of the University of London, now of Cambridge University, leans rather to the modern and more liberal view. He says:[18]

The doctrine was formerly held, and a few writers maintain it even now, that the outbreak of war *ipso facto* cancels all treaties previously concluded between the belligerents, such treaties only excepted as have been concluded especially for the case of war. The vast majority of modern writers on International Law have abandoned this standpoint, and the opinion is pretty general that war by no means annuls every treaty. But unanimity in regard to such treaties as are and such as are not cancelled by war does not exist. Neither does a uniform practice of the states exist, cases having occurred in which states have expressly declared that they considered all treaties annulled through war. Thus the whole question remains as yet unsettled. But nevertheless with the majority of writers a conviction may be stated to exist on the following points:

. . . .

3. Such political and other treaties as have been concluded for the purpose of setting up a permanent condition of things are not *ipso facto* annulled by the outbreak of war, but in the treaty of peace nothing prevents the victorious party from imposing upon the other party any alterations in, or even the dissolution of, such treaties.

[16] Emer de Vattel, "Le Droit des Gens ou Principes de la Loi Naturelle." A Amsterdam chez E. van Harrevelt, 1775, Vol. II., p. 81.

[17] Robert Phillimore, "Commentaries upon International Law," Philadelphia, 1857, Vol. III., p. 457, et seq.

[18] L. Oppenheim, "International Law," London, 1906, Vol. II., p. 107.

Henry Wheaton, an American, says that all treaties are not terminated by war.[19]

Englishmen, too, holding Government positions, have thought that not all treaties were abrogated by war. Thus in February, 1765, Sir James Marriott, the advocate-general, held that the treaty of neutrality of 1686 between Great Britain and France was "a subsisting treaty, not only because it is revived, by a strong implication of words and facts but for that it may be understood to subsist because it never was abrogated."[20] And speaking in the House of Commons in 1783, Charles James Fox gave it as his opinion that all treaties were not ended by a subsequent war between the contracting nations.[21]

From 1815 to 1818 Great Britain continued to maintain, in spite of the third article of the Treaty of 1783, that American fishermen had no right to fish in British territorial waters; and during those years British government vessels seized numerous American vessels found fishing in British waters. These seizures and the consequent partial stoppage of the fishing rights of the American fishermen created much bad feeling.

In order to avoid this continual cause of friction between the American republic and the British empire, which kept alive and inflamed the bad feelings between the peoples of the two nations, the two governments agreed on October 20, 1818, on a convention to settle the fishery controversy on the principle of mutual concessions. This convention was negotiated for the United States by Albert Gallatin and Richard Rush, and for great Britain by Frederick J. Robinson and Henry Soylburn. The fishing rights of Americans in the British territorial waters were defined in Article one that read as follows:[22]

Article I. Whereas differences have arisen respecting the liberty claimed by the United States for the inhabitants thereof, to take, dry, and cure fish

[19] Henry Wheaton, "Elements of International Law," eighth edition, edited by Richard Henry Dana, Jr., Boston, 1866, p. 340.

[20] George Chalmers, "Opinions of Eminent Lawyers, on Various Points of English Jurisprudence, Chiefly Concerning the Colonies, Fisheries and Commerce of Great Britain," London, 1814, Vol. II., p. 355.

[21] Hansard, "Parliamentary Debates," Vol. XVIII., London, 1814, p. 1147.

[22] "Treaties and Conventions concluded between the United States of America and other Powers since July 4, 1776," Washington, 1889, p. 415.

on certain coasts, bays, harbours, and creeks of His Britannic Majesty's dominions in America, it is agreed between the high contracting parties, that the inhabitants of the said United States shall have forever, in common with the subjects of His Britannic Majesty, the liberty to take fish of every kind on that part of the southern coast of Newfoundland which extends from Cape Ray to the Rameau Islands, on the western and northern coast of Newfoundland, from the said Cape Ray to the Quirpon Islands, on the shores of the Magdalen Islands, and also on the coasts, bays, harbours, and creeks from Mount Joly on the southern coast of Labrador, to and through the Streights of Belleisle and thence northwardly indefinitely along the coast, without prejudice, however, to any of the exclusive rights of the Hudson Bay Company: And that the American fishermen shall also have liberty forever, to dry and cure fish in any of the unsettled bays, harbours, and creeks of the southern part of the coast of Newfoundland hereabove described, and of the coast of Labrador; but so soon as the same, or any portion thereof, shall be settled, it shall not be lawful for the said fishermen to dry or cure fish at such portion so settled, without previous agreement for such purpose with the inhabitants, proprietors, or possessors of the ground. And the United States hereby renounce forever, any liberty heretofore enjoyed or claimed by the inhabitants thereof, to take, dry, or cure fish on, or within three marine miles of any of the coasts, bays, creeks, or harbours of His Britannic Majesty's dominions in America not included within the above-mentioned limits; Provided, however, that the American fishermen shall be admitted to enter such bays or harbours for the purpose of shelter and of repairing damages therein, of purchasing wood, and of obtaining water, and for no other purpose whatever. But they shall be under such restrictions as may be necessary to prevent their taking, drying or curing fish therein, or in any other manner whatever abusing the privileges hereby reserved to them.

By this new agreement both sides gave up something, and, as they thought at the time, they also in that way expected to peacefully adjust the whole northeastern fishery question for the future. The march of time and events have shown how far wrong the two governments were in the latter hope. And to-day what is meant by the language of the first article of that treaty is in dispute between the two powers, and the fishery question remains for all practical purposes as unsettled to-day as it was before the negotiation of the convention of 1818.

A comparison of the provisions of the Treaty of 1783 and that of 1818 in reference to the fisheries, shows that the right of Americans to catch fish in the Gulf of Saint Lawrence, on the Newfoundland Banks, and at all other places in the sea, remain the same. In other words, that both diplomatic agreements confirm the rights of Americans to take fish on the high seas, that is in all

waters that are not known as territorial. But the liberty granted to American fishermen to fish within British territorial waters by the Treaty of 1783 is much curtailed by the convention of 1818. The former instrument gave to Americans the liberty to fish along the British coasts generally and "to dry and cure fish in any of the unsettled bays, harbors and creeks of Nova Scotia, Magdalen Islands and Labrador, so long as the same shall remain unsettled." The convention of 1818 curtailed the liberty of Americans to fish in British territorial waters to the shores of Newfoundland, along its southern coast from Cape Ray to the Rameau Islands and on its western and northern sides from Cape Ray to the Quirpon Islands; to the shores of the Magdalen Islands in the Gulf of Saint Lawrence; and to the coast of Labrador from Mount Joly indefinitely to the east and the north.

On June 14, 1819, the British Parliament passed an act to carry the first article of the convention of 1818, which specified the rights of Americans to take fish in the waters around Newfoundland, into effect.

Everything on the fishing grounds did not run smoothly. A number of American fishing vessels were seized by the British authorities. Correspondence upon the subject between the constituted authorities of the two powers resulted from 1822 to 1826.[23] Then for a decade, comparative quiet seems to have reigned concerning the fishery rights. In 1836, however, the legislature of Nova Scotia began to attempt to prevent American fishing vessels from catching fish in the waters adjoining the shores of Nova Scotia. First it passed a "hovering act," to prevent American fishing vessels from sailing within three miles of the coast; then Nova Scotia sought to exclude American fishermen from all bays, including even the Bay of Fundy, which is over sixty miles wide and nearly a hundred and forty miles long, that are bound by the shores of Nova Scotia.[24] That province also attempted to deny to American vessels the right

[23] Senate Executive Documents, No. 100, 32d Congress, 1st Session, Washington, 1852, pp. 1–55.

[24] Senate Executive Documents, No. 100, 32d Congress, 1st Session, Washington, 1852, p. 108.

of free passage through the Gut of Canso between Nova Scotia and Cape Breton.[25]

The British authorities based their rights to exclude American vessels from fishing in the Nova Scotia bays, no matter what their area, upon the renunciation by the United States in the first article of the convention of 1818 "to take, dry, or cure fish on, or within three marine miles of any of the coasts, bays creeks, or harbors of his Britannic Majesty's Dominions in America" outside of those of the shores of the Magdalen Islands, the coasts of Canada and Labrador east and north of Mount Joly, and a part of the shores of Newfoundland. To this preposterous claim of the British authorities, that ran counter to the accepted Law of Nations that had gradually opened the high seas to the vessels of all nations *except* within three miles of the shore and within those bays and fiords that were less than six miles wide, the American government protested. American fishing vessels were seized within the Bay of Fundy by the British authorities. Conscious that this attempt to apply territorial rights to such a large body of water, which obviously constituted a part of the high seas, was in contravention of the Law of Nations, the British government in 1845 gave up its claim as to the Bay of Fundy, stating, however, that it made this concession as to that one bay only.[26] Daniel Webster, Secretary of State for America, and Lord Malmesbury for Britain, stated in 1852 the views of the two countries. In the summer of the same year, Senator Cass, in the United States Senate, spoke on this question. He illuminated the subject by referring to the last part of article one of the convention of 1818 which provided that "American fishermen shall be admitted to enter such bays or harbors for the purpose of shelter and of repairing damages therein, of purchasing wood, and of obtaining water," and argued that this language meant the small bays into which vessels were accustomed to seek shelter from storms. Senator Cass said:

[25] Lorenzo Sabine, "Report on the Principal Fisheries of the American Seas," House of Representatives, Miscellaneous Documents, No. 31, 42d Congress, 2d Session, p. 221.

[26] Documents of the United States Senate, Special Session called March 4, 1853, Washington, 1853, Senate Document 3, pp. 4–8, 9–21.

That such was the understanding of our negotiators is rendered clear by the terms they employ in their report upon this subject. They say: "It is in that point of view that the privilege of entering the ports for shelter is useful," etc. Here the word "ports" is used as a descriptive word, embracing both the bays and harbors within which shelter may be legally sought, and shows the kind of bays contemplated by our framers of the treaty. And it is not a little curious that the Legislature of Nova Scotia have applied the same meaning to a similar term. An Act of that Province was passed March 12, 1836, with this title: "An act relating to the fisheries in the Province of Nova Scotia and the coasts and harbors thereof," which act recognizes the convention, and provides for its execution under the authority of an imperial statute. It declares that harbors shall include bays, ports, and creeks. Nothing can show more clearly their opinion of the nature of the shelter secured to the American fishermen.[27]

In 1853 America and Great Britain agreed to a convention, whereby a settlement of all claims by citizens or corporations of either country against the other should be referred to a mixed commission, composed of two commissioners, one for each nation.[28] In every case where the commissioners could not agree the convention provided that they should refer it to an umpire. In that way the claims arising out of the seizures by the Canadian authorities in 1843 of the American fishing vessel, *Washington*,[29] while fishing in the Bay of Fundy, ten miles from shore, and in 1844 of the American schooner, *Argus*,[30] on St. Ann's Bank, twenty-eight miles from the nearest land, were referred for settlement to the umpire, Mr. Bates, an American by birth, residing in England where he was a member of the banking house of Baring. In both cases he awarded damages to the American owners, on the ground that in neither case were the American vessels fishing in contravention of the convention of 1818.

With the object of amicably adjusting the various controversial points that had arisen under the interpretation of the convention of 1818, the British government in 1854 sent Lord Elgin to America to

[27] "Congressional Globe," 32d Congress, 1st Session, Appendix, Washington, 1852, p. 895.

[28] "Treaties and Conventions concluded between the United States of America and other Powers since July 4, 1776," Washington, 1889, p. 415.

[29] Senate Executive Document, No. 103, 34th Congress, 1st Session, Washington, 1856, p. 184.

[30] Senate Executive Document, No. 113, 50th Congress, 1st Session, Washington, 1888, p. 59.

negotiate with the American government to that end. And on June 5, 1854, the Hon. William L. Marcy, the American Secretary of State, and Lord Elgin, special British envoy, concluded a treaty relating to the fisheries, commerce and navigation. By its provisions liberty was extended to American fishermen to catch fish of all kinds, "except shellfish," in British or Canadian territorial waters over and above the British territorial waters in which they had the *right* to fish by the convention of 1818.[61] The treaty extended a similar liberty to British subjects of fishing in the American Atlantic territorial waters above the thirty-sixth parallel of north latitude. It provided also for reciprocal free trade between America and the British North American colonies in various articles; and prescribed certain regulations for the navigation of the Saint Lawrence River, Lake Michigan and such Canadian Canals as were necessary to an all water way communication between the Atlantic Ocean and the Great Lakes. The treaty went into effect on March 16, 1855, and, according to the notice of the United States terminated March 17, 1866. During this period friction over the fishery rights of American fishermen reserved in British waters by the convention of 1818 were happily avoided. And upon the termination in 1866 of the reciprocity treaty of 1854, the Canadian government, for three years, granted licenses to American fishing vessels, at so much a ton, to exercise the same liberties they had obtained under the treaty of 1854.

For the fishing season of 1870 the practice of granting licenses to the American vessels was stopped, and the British government notified the government of America that her Britannic Majesty's government was of the opinion that by the convention of 1818 the American government had "renounced the right of fishing, not only within three miles of the colonial shores, but within three miles of a line drawn across the mouth of any British bay or creek." This communication continued:

> It is, therefore, at present the wish of Her Majesty's government neither to concede nor for the present to enforce any rights which are in their nature open to any serious question. Even before the conclusion of the reciprocity

[61] "Treaties and Conventions concluded between the United States of America and other Powers since July 4, 1776," Washington, 1889, p. 449.

treaty Her Majesty's government had consented to forego the exercise of its strict right to exclude American fishermen from the Bay of Fundy, and they are of opinion that during the present session that right should not be exercised in the body of the Bay of Fundy, and that American fishermen should not be interfered with, either by notice or otherwise, unless they are found within three miles of the shore, or within three miles of a line drawn across the mouth of a bay or creek which is less than ten geographical miles in width, in conformity with the arrangement made with France in 1839.[32] . . . Her Majesty's government do not desire that the prohibition to enter British bays should be generally insisted on, except when there is reason to apprehend some substantial invasion of British rights. And in particular they do not desire American vessels to be prevented from navigating the Gut of Canso (from which Her Majesty's government are advised they may lawfully be excluded), unless it shall appear that this permission is used to the injury of colonial fishermen, or for other improper objects.[33]

On November 25, 1870, an American vessel, the *White Fawn*, was seized at Head Harbor, New Brunswick, because she had bought herrings intended to be used as bait for fishing. Judge Hazen, of the vice-admiralty court of St. John's, before whom the case of whether she was liable to forfeiture came, held that though she had bought bait within the British territorial waters, she had not actually proceeded to catch fish with it, and consequently that the seizure could not be sustained.[34]

Previously in June, 1870, the British authorities seized in the North Bay of Ingonish, on the shore of Cape Breton Island, the American fishing vessel, *J. H. Nickerson*. They charged her with entering to procure bait and of having obtained it. The case came before Sir William Young in the vice-admiralty court at Halifax. In his decision November 15, 1871, while he condemned the vessel to forfeiture because she had bought bait in a British port preparing to fish, Sir William Young admitted that had she merely entered to buy bait without the intention of fishing, she would have been acting within her rights.[35]

[32] On this point see Westlake, "International Law," Cambridge, 1904, Part I., pp. 184, 187.

[33] "Foreign Relations of the United States, 1870," Washington, 1870, pp. 419-420.

[34] "Award of the Fishery Commission: Documents and Proceedings of the Halifax Commission, 1877," Washington, 1878, Vol. III., p. 3381.

[35] "Award of the Fishery Commission: Documents and Proceedings of the Halifax Commission, 1877," Washington, 1878, Vol. III., p. 3395.

Commenting on this decision Wharton says:[86]

In the case here cited there ought to have been no conviction, even under the statute, unless it could have been shown that the purchase was a preparation to fish within the forbidden belt, and that this was put in process of execution. Sir W. Young's dictum on this point, therefore, cannot be sustained as a matter of municipal law. As a ruling of international law it is of no authority, since preparing to fish without fishing is in any view not a contravention of the treaty of 1818. But Sir W. Young's ruling, on the merits, coincides with that of Judge Hazen, since he concedes that merely buying fish within the three miles is not a violation of the treaty.

In order to eliminate the friction caused by such seizures of American vessels in the British fishing grounds, the American- British Joint High Commission, which met in Washington in February, 1871, to negotiate a comprehensive treaty whereby "the Alabama Claims," the chief cause of difference between the two countries, should be submitted to a satisfactory form of arbitration,[87] and all other points of difference between America and England then causing friction and dispute and liable to imbitter their peaceable relations should be satisfactorily adjusted, took up for solution with other questions that of the northeastern fisheries. In respect to that question, the Treaty of Washington of May 8, 1871, extended facilities and liberty to American fishermen to take fish in the sea fisheries, and to British fishermen like facilities and liberty to catch fish in the American Atlantic sea fisheries north of the thirty-ninth parallel of north latitude.[88] The treaty provided for reciprocal free trade for a term of years of "fish-oil" and the fish taken from the sea fisheries between America, and Canada and Newfoundland.

As a result of the Treaty of Washington of 1871, the difficulties arising from the divergence of the views of the two governments as to the rights of American citizens to catch fish in the British North American colonial waters, were mostly, during the time the treaty was in operation, smoothed over. However, in Fortune Bay, Newfoundland, on Sunday, January 6, 1878, the local inhabitants, pre-

[86] Francis Wharton, "A Digest of the International Law of the United States," Washington, 1887, Vol. III., p. 53.

[87] Thomas Balch, "International Courts of Arbitration, 1874," 3d edition, Philadelphia, 1899.

[88] "Treaties and Conventions concluded between the United States of America and other Powers since July 4, 1776," Washington, 1889, p. 486.

vented from fishing by local regulations of Newfoundland, attacked some American fishermen, who, invoking the protection of the provisions of the treaty of 1871, prepared to fish.[39] The Newfoundlanders destroyed the boats and nets of the Americans. In the official correspondence that ensued, the British government argued that the treaty granted to the Americans only the right to fish in common with British subjects, and thus the former were amenable to the local Newfoundland laws and regulations.

The American authorities contended that the local laws could not be allowed to regulate or prescribe the provisions of the treaty; in addition they maintained that damages were due the American fishermen because of the violent attack on them. Eventually this dispute was adjusted by a money payment by Great Britain to the United States of £15,000 "without prejudice to any question of the rights of either government under the treaty of Washington."[40] Except for this incident the fishing seemed to proceed smoothly until, upon the giving of due notice by the United States, the provisions of the treaty of 1871 regulating the fisheries came to an end on July 1, 1885. As a result of informal negotiations between Secretary Bayard for America, Minister West for Great Britain, and Sir Ambrose Shea for Canada, it was agreed that the privileges of inshore fishing in the respective American and British waters to which the provisions of the treaty had applied would be continued for the whole season of 1885.

In the year 1886 the Canadian authorities seized many American fishing vessels.

On May 6 of that year the Canadian steamer *Landsdowne* seized in Annapolis Basin, Nova Scotia, a landlocked harbor, where it would seem ridiculous to suppose that an American vessel would attempt to fish, the *David J. Adams* of the American fishing fleet.[41] She was then taken by the Canadian authorities to Saint Johns, New Brunswick, and on May 10 brought back to Digby, Nova Scotia,

[39] House Executive Documents, No. 84, 46th Congress, 2d Session, Washington, 1880.

[40] "Foreign Relations of the United States, 1881," Washington, 1882, p. 509.

[41] "Foreign Relations of the United States, 1886," Washington, 1887, pp. 341–346, 373–380, 396–404.

without any explanation or hearing being given to her captain. At Digby, a paper, which was alleged to be the legal precept for her capture and detention, was nailed to her mast. But this alleged writ was placed so high that it could not be read. The Canadian authorities refused the requests of both the captain of the vessel and of the American Consul General to be allowed to detach this paper in order to learn its contents Neither would the captain of the *Landsdowne* tell the American Consul General the ground upon which he had captured the American vessel. After many vigorous protests by Secretary Bayard and Minister Phelps to Lord Rosebery, the British Foreign Secretary, Sir Lionel Sackville West, the British Minister at Washington, communicated to Mr. Bayard a minute of the Canadian privy council that agreed that the condemnation proceedings against the *David J. Adams* should be stopped for the alleged violation of the fishery statutes, provided that the owners of the vessels would agree that they would not base upon this discontinuance a claim for damages or expenses. This minute of the Canadian privy council was practically an avowal that the seizure of the *David J. Adams* had been made without good or sufficient cause.[42]

On October 7, 1886, a little before midnight, the American fishing vessel, *Marion Grimes,* arrived seeking refuge from a storm at sea, at the outer harbor of Shelbourne, Nova Scotia.[43] She anchored about seven miles from the port of Shelbourne, no one leaving her until six o'clock the next morning. She then hoisted sail and stood out to sea. As soon as she had started, however, the Canadian cruiser *Terror* sent a boat's crew to arrest the *Marion Grimes.* Captain Landry of the American vessel, was then forced to proceed to Shelbourne to appear before the collector of customs there. In spite of the fact that the customs house was closed during the night, that the storm proved he had merely sought a haven of refuge from its violence, that he had stayed a very short time and that the *Marion Grimes* was equipped only for deep sea fishing, Captain Landry

[42] "Foreign Relations of the United States, 1888," Washington, 1889, Part I., p. 802.

[43] "Foreign Relations of the United States, 1886," Washington, 1887, pp. 362–370.

was fined $400. This fine was imposed chiefly by the insistence of Captain Quigley, commander of the *Terror*. Captain Landry then applied to Mr. White, the American consular agent. Owing to the importance to the success of the venture of the *Marion Grimes* that she should not be detained, Mr. White at once telegraphed the facts of the case to Mr. Phelan, the American Consul General at Halifax. Mr. Phelan took the matter up with the assistant commissioner of customs at Ottawa, who replied the fine could not be reduced, but that the $400 could be deposited at Halifax, to await a decision in the case. Mr. Phelan made the deposit at Halifax and telegraphed to Captain Landry he was at liberty to take his vessel to sea. On October 11, Captain Landry, whose vessel had by that time been held up four days, telegraphed to Consul General Phelan that "the custom-house officers and Captain Quigley" refused to let him go to sea. The next morning the consul general called on the collector of Halifax to learn if the order to release the *Marion Grimes* had been issued, and was told such an order was sent, "but that the collector and the captain of the cruiser refused to obey it, for the reason that the captain of the seized vessel hoisted the American flag while she was in custody of the Canadian officials." Mr. Phelan telegraphed this news to the assistant commissioner at Ottawa, and received a reply dated October 12 that the "collector had been instructed to release the *Grimes* from customs seizure. This department has nothing to do with other charges." The same day the collector of customs at Halifax sent a dispatch to the collector at Shelbourne to release the *Marion Grimes,* in which he said that "this department (customs) has nothing to do with the other charges. It is the department of marines."

What happened concerning the hoisting of the American flag by the captain of the *Marion Grimes* over his vessel was thus told by Secretary Bayard in a dispatch to Minister Phelps:

> On October 11 the *Marion Grimes,* being then under arrest by order of local officials for not immediately reporting at the custom house, hoisted the American flag. Captain Quigley who, representing, as appeared, not the revenue, but the marine department of the Canadian administration, was, with his "cruiser" keeping guard over the vessel, ordered the flag to be hauled down. This order was obeyed; but about an hour afterwards the flag was again hoisted, whereupon Captain Quigley boarded the vessel with an armed

crew and lowered the flag himself. The vessel was finally released under orders of the customs department, being compelled to pay $8 in addition to the deposit of $400 above specified.

For this insult to the American flag, Secretary Bayard demanded an apology, and December 7, 1886, the British Minister at Washington, under instruction from the Earl of Iddesleigh, British Secretary of Foreign Affairs, communicated to the American government a communication from the government of the Dominion of Canada apologizing for the hauling down of the flag of the *Marion Grimes* by Canadian officials.[44]

Owing to this harassing of American fishermen in Canadian territorial waters, under the guise that they transgressed the Canadian customs regulations, the American Congress on March 3, 1887, approved an act whereby power was given to the president to retaliate upon the Canadians.

Negotiations, with a view to arrange an amicable settlement were continued by the American and the British governments.[45] Finally a convention was agreed upon at Washington, February 15, 1888, subject to ratification by the American Senate, the Canadian Parliament and the Newfoundland Legislature.[46]

This convention provided that the width of exclusively territorial bays, wherein American fishermen were excluded from taking fish by the Treaty of 1818, should be extended from six miles from shore to shore, according to the well-recognized and established custom of International Law, to a distance of ten miles from land to land. Thereby the extent of Canadian and Newfoundland territorial waters from which American fishing vessels were barred was increased. In addition, the convention restricted American fishermen from fishing in specifically named bays, such as the Baie des Chaleurs in New Brunswick, and Fortune Bay in Newfoundland, that varied in width from ten to twenty-one miles from shore to

[44] "Foreign Relations of the United States, 1886," Washington, 1887, pp. 491, 492.

[45] Senate Executive Documents, No. 113, 50th Congress, 1st Session, Washington, 1888, pp. 56–65, 112–119.

[46] Senate Executive Documents, No. 113, 50th Congress, 1st Session, Washington, 1888, pp. 127–142. Joseph I. Doran, "Our Fishery Rights in the North Atlantic," Philadelphia, 1888, pp. 54–67.

shore. In that way the extent of territorial waters from which American fishermen were excluded under the treaty of 1818 was still further extended. The convention guaranteed free passage to American *fishing vessels* through the Gut of Canso,[47] a right to which they were entitled by the Law of Nations. The convention also provided a right of refuge to American fishermen in Canadian ports fleeing from the danger of storms—a right to which all seafaring men are entitled in the ports of all civilized countries—and, when the American vessels needed to make repairs, the privilege to land their catch and tranship it to America.

In view of the very great advantages that were given by this convention to Canada and Newfoundland in exchange for rights which American fishing vessels already possessed under the Law of Nations without any grant by treaty from either Canada or Newfoundland, the American Senate very properly refused August 21, 1888, to confirm the convention, and so it failed to become a treaty.

During the latter part of 1890 and the beginning of 1891, Secretary Blaine for America and Sir Julian Pauncefote for Great Britain held numerous parleys concerning the fishery question as between America and Newfoundland. Their negotiations finally resulted in a convention known as the Blaine-Bond Convention, since Sir Robert Bond, the Newfoundland premier, inspired the negotiations of the British Minister.[48] This convention was to last for five years from the date it should go into operation, and might thereafter be renewed from year to year. It provided that American fishing vessels entering Newfoundland waters should have the privilege of buying bait on the same terms as Newfoundland fishing vessels. Also it was agreed that American fishing vessels should "have the privilege of touching and trading, selling fish and oil, and procuring supplies in Newfoundland, conforming to the harbor regulations, but without other charge than the payment of such light, harbor and customs dues as are or may be levied on New-

[47] Senate Executive Documents, No. 113, 50th Congress, 1st Session, Washington, 1888, p. 135. John Westlake, "International Law," Cambridge University Press, 1904, Part I., p. 193.

[48] "Convention between the United States of America and Great Britain, for the Improvement of Commercial Relations between the United States and Her Britannic Majesty's Colony of Newfoundland." This unratified agreement is known as the Blaine-Bond Convention.

foundland fishing vessels." The convention provided for a reciprocal free exchange of various American and Newfoundland products. To make the convention operative the plenipotentiaries agreed that it should be subject to ratification by the American Senate and Her Britannic Majesty, and that it should "take effect as soon as the laws required to carry it into operation shall have been passed by the Congress of the United States on the one hand, and the Imperial Parliament of Great Britain and the provincial legislature of Newfoundland on the other." Owing to a vigorous protest from the Canadian government, the British imperial government in a memorandum addressed on May 21, 1891, by the British Legation at Washington to the State Department, notified the American government that it could not agree to ratify the convention, "unless *pari passu* with the proposed Canadian negotiations."

A joint commission of two experts, one named by each government, to examine and report upon the subject was agreed upon in 1892; and the commission reported early in 1897.

The northeastern fisheries question was included in the work submitted for adjustment to the American-British Joint High Commission that met and organized for business at Quebec, August 23, 1898. Owing to the Joint High Commission being unable to come to a satisfactory agreement concerning the eastern frontier of the Alaska *lisière,* which was then in dispute between the American republic and the British empire, the Joint High Commission adjourned in March, 1899, without having arranged the fisheries or any other of the questions submitted to it.[49]

In 1895 and again in 1898 Canada unsuccessfully sought reciprocity herself. Secretary of State Hay and Ambassador Herbert took up at Washington the discussion of the fisheries as between America and Newfoundland and finally agreed on November 8, 1902, upon a new convention, known after the American Secretary of State and the Newfoundland premier who inspired the negotiations of the British Ambassador, as the Hay-Bond Convention.[50]

[49] Thomas Willing Balch, "The Alaska Frontier," Philadelphia, 1903, pp. 162, 168.

[50] Senate Executive Documents, No. 49, 57th Congress, 2d Session. "A Convention with Great Britain, signed at Washington on November 8, 1902, for the Improvement of Commercial Relations with Newfoundland."

As in the case of the Blaine-Bond Convention of 1891, the Hay-Bond Convention of 1902 provided that the American fishing vessels should fish in the Newfoundland waters subject to the local Newfoundland regulations regulating Newfoundland fishing vessels. The convention also provided for reciprocal free trade concessions, whereby Newfoundland gained vastly more than she gave.[51]

The Hay-Bond Convention remained in the Senate Committee on Foreign Relations unacted on, for three years. On June 15, 1905, the Newfoundland government enacted an act intended to hamper the American fishing vessels in their lawful occupation of taking fish under the provisions of the first article of the Treaty of 1818.[52] In the autumn of 1905, Premier Bond notified Secretary Hay of certain concessions he was willing to have inserted in the Hay-Bond Convention in the form of senate amendments. After these amendments were added by the Committee on Foreign Relations, the Senate as a whole made further changes that it was so clear would not be satisfactory to Newfoundland, that the convention as amended was never brought to a vote in the Senate and so never became a treaty.

In view of the probable serious interference by the Newfoundland authorities with the American fishing vessels in taking fish in those territorial waters of Newfoundland on the southern coast of Newfoundland from Cape Ray eastward to the Rameau Islands, and up along the western coast of the island from Cape Ray and round on the north coast to Quirpon Islands as guaranteed to them by the Treaty of 1818, Mr. Root, the American Secretary of State, wrote on October 19, 1905, to Sir Mortimer Durand, the British Ambassador at Washington, an expression of some of the views held on the fisheries question by the American government. Reasserting once again the view of the American government of the right of American fishing vessels to fish in the treaty waters unhampered by the local regulations of Newfoundland, he said:[53]

[51] Speech of Senator Henry Cabot Lodge, April 2, 1903.

[52] "Supplement to the American Journal of International Law," James Brown Scott, chief editor, January, 1907; "An Act of Newfoundland Respecting Foreign Fishing Vessels," p. 22.

[53] "Foreign Relations of the United States," 59th Congress, 1st Session, 1905. House Documents, Vol. I., Washington, 1906, p. 491.

Any American vessel is entitled to go into the waters of the treaty coast and take fish of any kind. She derives this right from the treaty (or from conditions existing prior to the treaty and recognized by it) and not from any permission or authority proceeding from the government of Newfoundland.

Secretary Root also called Sir Mortimer Durand's attention to the evident hostile animus of the colony of Newfoundland towards American fishing vessels as shown by the "Foreign Fishing Act" enacted the previous June by the Newfoundland government.[54] The provisions in that act that gave authority to Newfoundland officials to search any foreign fishing vessel in any of the territorial waters of Newfoundland and upon finding any bait or fishing apparel to arrest and bring the vessel into port, Secretary Root pointed out were a clear and palpable infringement of American rights under the Treaty of 1818 in the treaty waters. Secretary Root also referred Sir Mortimer Durand's attention, as a result of the Newfoundland legislation that prohibited the sale of bait by the Newfoundlanders to American fishing vessels, to the unrest and profound dissatisfaction existing among the local population living along the shores of or near the "Bay of Islands" on the west coast of Newfoundland with the resulting situation and the risk of serious violence resulting therefrom.

To these observations of the American Secretary, the British Ambassador in reply enclosed in a note of February 2, 1906, to Mr. Reid, the American Ambassador at London, a memorandum of Sir Edward Grey, the British Foreign Secretary.[55] In this memorandum the British government replied that the privileges of fishing "conceded" by the Treaty of 1818 in some of the territorial waters of Newfoundland were "conceded, not to American vessels, but to inhabitants of the United States and to American fishermen." The British memorandum reasserted the old view enunciated by Earl Bathurst, that by the Treaty of 1818 "a new grant to inhabitants of the United States of fishing privileges within the British Jurisdiction" was made. In the memorandum it was further maintained that "American fishermen" could not claim to exercise the right of

[54] "Supplement to the American Journal of International Law," January, 1907, p. 22.

[55] "Supplement to the American Journal of International Law," October, 1907, p. 355.

fishing within the territorial waters of Newfoundland "on a footing of greater freedom than the British subjects 'in common with' whom they exercised it under the convention. In other words, the American fishery under the convention is not a free but a regulated fishery, and, in the opinion of His Majesty's government, American fishermen are bound to comply with all colonial laws and regulations, including any touching the conduct of the fishery, so long as these are not in their nature unreasonable, and are applicable to all fishermen alike." The British note went on to argue that all American and other foreign vessels sojourning within British territorial waters should obey the local law, "and that, if it is considered that the local jurisdiction is being exercised in a manner not consistent with the enjoyment of any treaty rights, the proper course to pursue is not to ignore the law, but to obey it, and to refer the question of any alleged infringement of their treaty rights, to be settled diplomatically between their government and that of His Majesty." In reply to Secretary Root's contention that the Newfoundland foreign fishing-vessel act of June 15, 1905, was directed against American fishing vessels so as to interfere with their rights in the treaty waters the British memorandum maintained that that act, especially the first and third sections, upon which Secretary Root had largely based his complaint, was not aimed at the rights of American vessels in particular. The memorandum referred to the seventh section of the act, as safeguarding "the rights and privileges granted by treaty to the subjects of any state in amity with His Majesty." And then the British note went on to admit that "the possession by inhabitants of the United States of any fish and gear which they may lawfully take or use in the exercise of their rights under the convention of 1818 cannot properly be made *prima facie* evidence of the commission of an offense, and, bearing in mind the provisions of section 7, they can not believe that a court of law would take a different view."

Nevertheless, this was an admission by the British Foreign Office that the act was so framed that the Newfoundland officials could, through legal processes, so harass and "hold up" an American fishing vessel that her trip would be rendered unprofitable, as happened in many cases during the latter eighties in the ports and terri-

torial waters of Nova Scotia, for example in the case of the *Marion Grimes*.

As a result of the views expressed by Secretary Root in his letter of October 19, 1905, the Newfoundland government repealed the act to which he objected and enacted on May 10, 1906, a second act relating to fishing in her territorial waters by foreigners.[56] The new act was drawn so as to avoid for American fishing vessels the two special provisions against which Secretary Root had complained, but at the same time new provisions that were added gave the power to obstruct and harass American vessels in their fishing ventures should it become advisable.

To the views of the British government as expressed in its memorandum of February 2, 1906, Secretary Root replied in an elaborate and able letter on June 30, 1906, addressed to the American Ambassador at London, Mr. Reid, by whom it was communicated to Sir Edward Grey.[57] Secretary Root protested in this letter against the possible inferences suggested in the memorandum that the Newfoundland government has the right to require of any American captain entering the treaty waters or any port of the colony to furnish evidence that all the members of his crew are inhabitants of the United States. and the Secretary of State denied the assertion that the colony of Newfoundland has the right irrespective of any agreement on the subject, between the parties to the Treaty of 1818, America and Great Britain, to interfere through local legislation with the American fishing vessels in the exercise of their fishery rights under the Treaty of 1818.

In previous correspondence regarding the construction of the Treaty of 1818, the government of Great Britain has asserted, and the memorandum under consideration perhaps implies, a claim of right to regulate the action of American fishermen in the treaty waters, upon the ground that those waters are within the territorial jurisdiction of the colony of Newfoundland. This government is constrained to repeat emphatically its dissent from any such view. The Treaty of 1818 either declared or granted a perpetual right to the inhabitants of the United States which is beyond the sovereign power of England to destroy or change. It is conceded that this right is, and forever

[56] "Supplement to the American Journal of International Law," January, 1907, p. 24.

[57] "Supplement to the American Journal of International Law," October, 1907, p. 364.

must be, superior to any inconsistent exercise of sovereignty within that territory. The existence of this right is a qualification of British sovereignty within that territory. . . .

For the claim now asserted that the colony of Newfoundland is entitled at will to regulate the exercise of the American treaty right is equivalent to a claim of power to completely destroy that right.

As a result of this vigorous exchange of views between the America and the British government, a *modus vivendi,* with the object of avoiding any clash between the American fishermen and the Newfoundland authorities or inhabitants during the fishing season of 1906–07, was concluded early in October, 1906, at London, between the two governments that were parties to the Treaty of 1818.[58] The British government agreed to the use of purse seines, and the shipment of Newfoundlanders by American vessels outside the three-mile limit. On the other hand the American government waived the right of American vessels to take fish on Sunday, and agreed that they would pay lighthouse dues, and where possible comply with the local customs regulations. The provisions of the Foreign Fishing Vessels Act of 1906 of Newfoundland, and the objectionable first and third sections of the Act of 1905 were not to apply to American vessels. With this agreement in force, the fishery of 1906–'07 was happily accomplished without untoward incident. At the beginning of September, 1907, a new *modus vivendi* to apply to the next fishery season was agreed to by the two interested nations.[59] This new *modus vivendi* was practically the same in its provisions as that of the previous season, except that the American government made a further concession of waiving the use of purse seines. In July, 1908, the modus vivendi of the previous year was renewed for the fishery of 1908–'09.[60]

In order to finally settle this vexatious dispute between the American republic and the British empire over the Atlantic fisheries question, in January, 1909, the two Powers at a conference held in Washington agreed to refer the matter to the decision of The Hague

[58] "Supplement to the American Journal of International Law," January, 1907, pp. 27–31.

[59] "Supplement of the American Journal of International Law," October, 1907, pp. 375–377.

[60] "Supplement of the American Journal of International Law," October, 1908, pp. 327–328.

International Court. At this conference, America was represented by Secretary of State Root, and the British empire, by Ambassador Bryce, who was aided by Mr. Aylesworth and Mr. Kent respectively for the Dominion of Canada and the Colony of Newfoundland.

In deciding upon the American-British Atlantic fisheries dispute The International Court at The Hague will be called upon, according to the terms of the Root-Bryce Treaty of January, 1909, to give its decision upon first the right of American fishing vessels under Article I. of the Treaty of 1818 to take fish in the bays and gulfs, more than six miles wide; whether the rights retained to inhabitants of the United States by the Treaty of 1818 concluded between America and Great Britain, two sovereign States members of the family of nations, can be regulated at will by the legislation of either Great Britain herself or one of her colonies or whether all changes or regulations applicable to the treaty can *only* be made by a mutual agreement between the original high contracting parties, the American republic and the British empire; and also, whether the inhabitant of the United States have the liberty under Article I. of the Treaty of 1818 to take fish in the territorial waters along that part of the southern coast of Newfoundland which extends from Cape Ray to the Rameau Islands, or along the western and northern coast of Newfoundland from Cape Ray to Quirpon Islands or in the territorial waters of Canada around the Magdalen Islands?

By an agreement, expressed in two letters exchanged on January 27, 1909, between Secretary Root and Ambassador Bryce, the right of American vessels to pass through the Gut of Canso and to take fish in the Bay of Fundy are not to be submitted for decision to the International Court at The Hague.

While the right of "innocent passage" by American vessels through the Gut of Canso will not be submitted to The Hague Court, yet the raising of that point by Canada in the past is too illuminative of the whole fishery question to pass it over without notice.

About 1839 the point was raised by the authorities of Nova Scotia that the Gut of Canso,[61] a passage of salt water connecting the Atlantic Ocean and the Gulf of Saint Lawrence that passed

[61] Senate Executive Documents, No. 100, 32d Congress, 1st Session, Washington, 1852, pp. 73–74.

between the Province of Nova Scotia and the neighboring island of Cape Breton, a part of the colony of Nova Scotia, was not a free passage to American vessels, because the Gut of Canso, which at some points was only a mile wide, belonged as territorial waters to Nova Scotia. Though this attempt to lay a claim to close the Gut of Canso as a free highway of the sea to American vessels was not seriously pushed at the time, the effort to claim the right to close it to American vessels was renewed in the Bayard-Chamberlain Convention of 1888.[62] In that instrument Canada proposed to guarantee to American fishing vessels the free passage through the Gut of Canso. But Canada was thereby undertaking to concede to America what already belonged to America as a right by the Law of Nations. Not only in 1888 but long before that it was a well-established principle of International Law that passages of the sea connecting two large bodies of water, were open to navigation by vessels of all powers.

Westlake, who for twenty years held the chair of International Law in Cambridge University, and for six years was one of the English members of The Hague International Court and to-day is in the forefront of international jurists, in speaking of the right of passage through straits, says:[63]

> If the strait connects two tracts of open sea, as the Gut of Canso between Cape Breton Island and the mainland of Nova Scotia, or the Straits of Magellan and the other passages in the extreme south of America, the lawful ulterior destination is clear, and there is a right of transit both for ships of war and for mechantmen.

Many other authorities can be cited to the same purpose, but in view of this clear statement by Westlake, who, together with Holland of Oxford, is one of Great Britain's leading living authorities on questions of International Law, it does not seem worth while.

The attempt at various times to include within the jurisdiction of Canada and Newfoundland bays and gulfs more than six miles in width, such as the Bay of Fundy and the Baie des Chaleurs, for instance, is an attempted restriction on the freedom of the high seas.

[62] Senate Executive Documents, No. 113, 50th Congress, 1st Session, Washington, 1888, p. 135.

[63] John Westlake, "International Law," Part I., "Peace"; Cambridge, 1904, p. 193.

Ever since the famous argument between Grotius and Selden as to whether the high seas should be free to the vessels of all the world or whether parts, greater or smaller as the case might happen to be, of the high seas should be subject to the jurisdiction of one nation, the verdict of the world has leaned more and more towards the view of the famous Hollander.[64] Practically all international jurists are agreed now that the high seas are free and that the territorial waters of a nation only extend to three miles from land and over those bays or portions of them that are not more than six miles across from shore to shore.

The learned Belgian jurist, Mr. Justice Nys, a member of the Court of Appeals of Brussels and of The Hague International Court, thus sums up the question of the freedom of the high seas. He says:[65]

> La haute mer, la pleine mer, la mer pour employer la désignation usuelle, est libre. Elle n'est pas susceptible de possession et de propriéte à cause de sa nature physique, de la mobilité et de la fluidité de ses flots, de l'étendue sur laquelle devrait s'appliquer la sanction des ordres ou des prohibitions; elle ne peut tomber sous le droit de police, de suprématie, d'empire d'un ou de plusieurs États à cause de l'egalité juridique des membres de la société internationale.

Oppenheim who now sits as successor to Westlake, by whom he was chosen, in the chair of International Law at Cambridge University, holds that many enclosed seas that are connected with the ocean by passages less than six miles in width are as free to navigation

[64] Le Comte de Garden, "Traité Complet de Diplomatie," Paris, 1833, Vol. I., pp. 402–404. A. G. Heffter, "Le Droit International de l'Europe; Quatrième édition Française, augmentée et annotée par F. Heinrich Geffcken," Berlin and Paris, 1883. F. de Martens, "Traité de Droit International," traduit du Russe par Alfred Léo, Paris, 1883, Vol. I., pp. 491–494. Alphonse Rivier, "Principes du Droit des Gens," Paris, 1896, Vol. I., pp. 236–237. Hannis Taylor, "A Treatise on International Public Law," Chicago, 1901, pp. 290–294. John Westlake, "International Law," Cambridge, 1904, Part I., pp. 160–163. Ernest Nys, "Les Origines du Droit International," Paris and Brussels, 1894, pp. 379–387; "Le Droit International, Les Principes, les Théories, les Faits," Paris and Brussels, 1905, Vol. II., pp. 135–138. L. Oppenheim, "International Law," London, 1905, Vol. I., pp. 300–306. George B. Davis, "Elements of International Law," New York, 1908, p. 57 *et seq.*

[65] Ernest Nys, "Le Droit International, Les Principes, les Théories, les Faits," Paris and Brussels, 1905, Vol. II., p. 134.

for the vessels of all nations as any part of the ocean. He says:[66]

The enclosure of a sea by the land of one and the same state does not matter, provided such a navigable connection of salt water as is open to vessels of all nations exists between such sea and the general body of salt water, even if that navigable connection itself be part of the territory of one or more riparian states. Wheras, therefore, the Dead Sea is Turkish and the Aral Sea is Russian territory, the Sea of Marmora belongs to the open sea, although it is surrounded by Turkish land and although the Bosphorus and the Dardanelles are Turkish territorial straits, because these are now open to merchantmen of all nations.

So, too, Hudson's Bay is a part of the high seas, for the entrance to that large interior sea to the vessels of all nations is through Hudson Strait that is much more than six miles wide.

It is only within territorial waters that a state can by its legislation restrict vessels of other nations from doing all those things that the vessels of all nations can properly do upon the high seas. What are the territorial waters of each state?

Phillimore, judge of the British High Court of Admiralty, says:[67]

The limit of territorial waters has been fixed at a marine league, because that was supposed to be the utmost distance to which a cannon-shot from the shore could reach. The great improvement recently effected in artillery seems to make it desirable that this distance should be increased, but it must be so by the general consent of nations, or by specific treaty with particular states.

The three-mile limit as the extent of the territorial waters of nations along their sea front, except where a modification has been made by treaty between the contracting parties, is to-day universally recognized.

With the aim of bringing about a universal change in the extent of the territorial belt of waters along the sea front of nations, the Institute of International Law in March, 1894, after careful consideration and weighing the arguments *pro* and *con*, gave it as its opinion that the belt of territorial waters along the coast line of each nation should be extended from three to six miles from low water.[68]

[66] L. Oppenheim, "International Law," London, 1905, Vol. I., p. 307.

[67] Sir Robert Phillimore, "Commentaries upon International Law," second edition, London, 1871, Vol. I., p. 237. Phillimore was a member of Her Majesty's Privy Council and judge of the High Court of Admiralty. The first edition of this volume appeared in 1854.

[68] Charles Calvo, "Le Droit International," Paris, 1896, cinquième edition, Vol. VI., p. 67.

And that in the case of bays the line from headland to headland that should show where the open sea ended should be twelve miles across, except in those cases where immemorial usage had consecrated a greater distance. In view of the modern development of arms and the more rapid means of communication and the vast expansion of commerce, this would seem to be a most admirable change in the universally existing recognition of the extent of territorial waters. But the Institute of International Law is a body of gentlemen learned in the Law of Nations and not a congress of representatives from all the nations of the earth with plenary powers to change the Law of Nations for the best interests of mankind. Consequently, however advisable the recommendation of the institute may be, it cannot change the extent of territorial waters unless the nations of the world agree. And America has not joined in any such agreement. But even if the American government had joined the governments of other nations to double the extent of the territorial belt of water, yet such an agreement would not alter the extent of the rights of American fishermen to catch fish in the Bay of Fundy, the Baie des Chaleurs and other smaller bodies of water as defined in the first Article of the Treaty of 1818. The limit of the area over which American fishing vessels can take fish along the coasts of the maritime provinces of the Dominion of Canada and Newfoundland, is limited only by the recognized three mile limit, except that in the treaty waters American vessels have rights to catch fish that the vessels of other nations do not possess.

In addition to attempting to offer to America the right for American fishing vessels to navigate the Gut of Canso and also to curtail the area over which they possess the right to catch fish in the high seas close to the shores of Canada and Newfoundland, both Canada and Newfoundland have sought by various local legislation to so hamper American fishing vessels in their just rights to take fish as to make their occupation unprofitable.

The aim of all these various attempts of Canada and Newfoundland to nullify the privileges of American fishing vessels as defined by article one of the Treaty of 1818 has been to force America to grant to Canada and Newfoundland favorable trade reciprocity. But the contracting parties to the Treaty of 1818 were neither Can-

ada nor Newfoundland. The contracting parties to that treaty were the American republic and the British empire. Of what use would it be for these two sovereign members of the family of nations to agree solemnly by treaty to define the respective rights of their subjects in the Atlantic fisheries, if power was reserved to either party by local legislation to completely nullify the plain and evident intent of the treaty which recognizes that American fishing vessels possessed in those waters certain rights and privileges to catch fish that the fishing vessels of all other nations do not possess under the ordinary Law of Nations. As Vattel justly says, treaties are sacred contracts between nations.[69]

The Brazilian jurist Calvo, after quoting in full the text of article one of the Treaty of 1818, says of the purpose of this article:[70]

> Rien dans cet article ne permet d'inférer que la Grande-Bretagne ait conféré aux États-Unis le droit de pêche. Ceux-ci n'ont fait que renoncer à certains privileges, ce qui implique, de la part de l'Angleterre, que ces privilèges existaient et que les États-Unis ont uniquement cédé une fraction de leur droit souverain. La Grande-Bretagne n'a pas dit aux États-Unis: "Venez seulement pour chercher un abri ou faire de l'eau ou du bois," mais les États-Unis disent à la Grande-Bretagne: "Nous, les proprietaires en commun de ces pêcheries consentons à ne pas prendre de poissons et à ne pas les secher ou les saler dans certaines limites, et à ne pas abuser d'ailleurs de privileges qui nous sont concédés."

And he goes on to say:[71]

> Jamais loi municipale ne saurait prévaloir sur une convention internationale.

The uselessness for members of the family of nations to make certain agreements by formal treaty, if those agreements could be nullified by the local legislation of a colony or province or state of a party to the treaty contract seems self-evident. In the constitution of the United States provision is made to insure the maintenance of

[69] Vattel, "Le Droit des gens," Paris and Lyons, 1820, Vol. II., p. 25.

[70] Charles Calvo, "Le Droit International Théorique et Pratique," cinquième édition. Vol. I., Paris, 1896, pp. 486–487.

[71] Charles Calvo, "Le Droit International Théorique et Pratique," cinquième édition, Paris, 1896, Vol. I., pp. 487–488.

international treaties entered into by the American federal government. Article sixth of the American Constitution says:[72]

> All treaties made or which shall be made, under the authority of the United States shall be the supreme law of the land; and the judges in every State shall be bound thereby, anything in the constitution or laws of any State to the contrary notwithstanding.

The chief powers of Europe at the London conference in 1871, on January 5, adopted, as the Russian jurist de Martens tells us, this principle:[73]

> The plenipotentiaries of the North German Confederation, Austria-Hungary, Great Britain, Italy, Russia and Turkey, to-day assembled *en conférence,* recognize that it is an essential principle of the Law of Nations that no power can liberate itself from the engagements of a treaty, nor modify its stipulations except with the consent of the contracting parties obtained by means of an amicable arrangement.

Thus Great Britain has affirmed the sanctity of treaties in a formal manner. Very properly America maintains that any modification of the rights of American fishing vessels under the Treaty of 1818, whether by amendment to that treaty or by police or maritime or customs or other regulation, can only be accomplished by agreement between the two parties to the contract known as the Treaty of 1818, the governments of the United States of America and of the British empire. Were an opposite doctrine recognized by the Hague International Court, what would become of the validity of many international treaties in force to-day between the nations of the earth. At the bar of the Hague International Court the United States of America will appear to defend the maintenance and sanctity of international contracts known under the generic name of treaties.

[72] For the argument of the strict constructionists see William E. Mikell, "The Extent of the Treaty Making Power of the President and the Senate of the United States," *University of Pennsylvania Law Review and American Law Register,* 1909, pp. 435–458, 528–562.

For the argument of the loose constructionists see Chandler P. Anderson, "The Extent and Limitations of the Treaty Making Power under the Constitution," *The American Journal of International Law,* July, 1907, pp. 636–670. See also the exhaustive treatise of Charles Henry Butler, "The Treaty-making Power of the United States," New York, 1902.

[73] F. de Martens, "Traité de Droit International," traduit du Russe par Alfred Léo, Paris, 1883, Vol. I., p. 546.

All through the negotiations relating to the fisheries question since the treaty of partition of 1783, the British empire and her two colonies of Canada and Newfoundland have sought to cut down the rights assigned by the partition treaty of 1783 to American citizens to catch fish in the territorial waters adjoining the Gulf of Saint Lawrence and the adjoining regions. Some of those rights America *consented* in the formal Treaty of 1818, concluded with the British imperial government, to give up. But not satisfied with the substantial gains then obtained, both Canada and Newfoundland through one subterfuge or another, have again and again tried to obtain more concessions from America by offering a shadow, as guaranteeing the right, for example, for American fishing vessels to navigate the Gut of Canso, for a reality. As in the case of the Alaska frontier where Canada's land claims grew greater with the passing of the years, so in this fisheries dispute the position of America on the one hand, and of Great Britain, Canada and Newfoundland on the other hand, is well summed up in the words with which Count Nesselrode, nearly ninety years since, contrasted the positions of the Muscovite and the British empires when they were discussing their Russo-British American frontier:

Ainsi nous voulons conserver, et les compagnies angloises veulent acquerir.

THE BURNING BUSH AND THE ORIGIN OF JUDAISM.

By PAUL HAUPT.

(Read April 23, 1909.)

Last autumn four members of our Society were invited by the German Emperor to attend the first performance of Friedrich Delitzsch's *Sardanapal* at the Royal Opera in Berlin. The climax of this historical pantomime, which is based on Lord Byron's tragedy *Sardanapalus* and a ballet of Paul Taglioni,[1] is the great pyre in the last scene, on which Sardanapalus burns himself with his queen, his attendants, and his treasures. The whole stage is full of fire; but, of course, nothing is burnt. The blaze is produced by steam with reflected red light. In the same way you see the stage full of fire in the last scene of Richard Wagner's musical drama *Die Walküre*. Wodan passes through the flames, but he is not scorched.

The black cloud over Mount Vesuvius has a fiery aspect at night, but this is merely the reflex of the fiery lava within the crater. The pillar of smoke over a volcano consists chiefly of steam and ashes. Volcanic eruptions are often not central, but lateral. The great eruption of *Mont Pelé* in the northern part of the island of Martinique, on May 8, 1902, was a lateral eruption. In the case of Mount Etna, lateral eruptions are more frequent than eruptions from the central crater. There are several hundred parasitic craters on the flanks of Mount Etna, especially on the southern side, in the zone between an altitude of 1,000 and 2,000 meters. This region is wooded. The volcano is covered with trees up to an altitude of 2,200 meters, and shrubs grow up to 2,500 meters. If there should be in this region a cloud of steam over a lateral crater, the shrubs around it might seem to be afire without being consumed. This, I

[1] Compare *Sardanapal. Grosse historische Pantomime in 3 Akten oder 4 Bildern, unter Anlehnung an das gleichnamige Ballet* Paul Taglioni's *neu bearbeitet von* Friedrich Delitzsch (Berlin, 1908).

think, is the *great sight* (Exodus, iii., 3) which Moses observed on the Mountain of God about 1200 B. C.

Mount Sinai is generally supposed to be a mountain on the so-called Sinaitic Peninsula between the Gulf of Suez and the Gulf of Akaba. The majority of scholars believe that the Mountain of the Law was the present *Jabal Mûsâ* (the Mountain of Moses) which is the highest point of this barren peninsula in the south, rising to a height of 7,362 feet; but the two famous Egyptologists Richard Lepsius and Georg Ebers claimed this distinction for the *Jabal Serbâl* in the northwest, which is 6,731 feet high.

Mount Sinai, however, cannot be located on the Sinaitic Peninsula; it was a volcano in the land of Midian on the northeastern shore of the Red Sea. Midian is not the name of an Arabian tribe; it denotes the Sinaitic amphictyony, *i. e.*, the league of worshipers of JHVH[2] in the neighborhood of Elath, the Edomite port at the northeastern end of the Red Sea.

Midian is derived from the old Sumerian word *dîn* which means in Arabic not only *judgment*, but also *religion*. Law and religion are intimately connected in the East. The Jewish religion is known as the Mosaic Law. In the New Testament the Jewish theologians are called *lawyers*.[3] The Arabic term *fakîh* denotes a scholar versed both in jurisprudence and theology.

Midianite is not a name like Arabic, but a term like Islamic. Priest of Midian means a priest of the Sinaitic amphictyony. The name of Moses's father-in-law was Jethro, which may be connected with the name of the Egyptian sun-god, Ra, which we find also in Potiphera' and Potiphar (for Petiphro; compare Jether for Jethro). In the original tradition, Moses was the son-in-law of a priest of On or Heliopolis, the city of the sun-god. Moses's Egyptian wife is contemptuously referred to (in Numbers, xii., 1) as the Ethiopian

[2] For JHVH (i. e., *Jahvêh* or *Yahwáy*, not *Jehovah*) see the notes on the translation of the Psalms, in the Polychrome Bible, page 164, line 4. The first syllable of JAHVEH should be pronounced like the *jah* in *Hallelujah*.

[3] Compare Matthew, xxii., 35; Luke, vii., 30; x., 25; xi., 45. 52; xiv., 3. It might be well to add that *publican* means *toll-gatherer*. *Sinner* = *unorthodox;* compare John, vii., 49.

woman, *i. e.*, the negress.[4] Afterwards this tradition was transferred to Joseph (Genesis, xli., 45).

Moses is not a proper name, but a title meaning *Deliverer*. He was an Edomite, but the son-in-law of an Egyptian priest of Heliopolis, near the western end of Goshen where the Edomite ancestors of the Jews lived before the Exodus. According to Acts vii., 22, Moses was learned in all the wisdom of the Egyptians.

If we bear this in mind, we can appreciate the remarkable statement in Deuteronomy, xxiii., 8 (which was written about 690 B. C.): Thou shalt not abhor an Edomite, for he is thy brother; thou shalt not abhor an Egyptian, for thou wast a stranger in his land. The children that are begotten of them shall enter into the congregation of JHVH in their third generation.

The Edomites were not enemies of their brethren in Jerusalem at the time of Nebuchadnezzar (about 586 B. C.) but they were unfriendly disposed toward the Jews at the time of Judas Maccabæus (about 164 B. C.). Both Môses and David were Edomites. Moses established the Jewish religion, David founded the kingdom of Judah. Moses corresponds to Mohammed, David to Omar. The Levites were Edomite priests. According to Exodus, ii., 1, Moses's father belonged to a priestly family (*bêth lêwî*) and Moses's mother was the daughter of a priest (*bath lêwî*).[5]

Jewish monotheism is derived from Egypt. Monotheism can have originated only in a highly civilized country as a reaction against excessive polytheism. About 1350 B. C. Amenophis IV. of Egypt endeavored to supersede the old polytheistic religion by the

[4] Compare Jeremiah, xiii., 23 and my paper *The Aryan Ancestry of Jesus* (Chicago, 1909) page 9 = *The Open Court* (April, 1909) page 201. The admixture of African blood in the Semitic race may be tested by the new sero-diagnostic methods (based on deviation of the complement—whereby the phenomenon of hæmolysis is inhibited) which were discussed by H. Sachs at the 39th congress of German anthropologists, held at Frankfort, Aug. 4, 1908. Compare Max Seber, *Moderne Blutforschung und Abstammungslehre* (Frankfurt am Main, 1909) page 44. See also, below, page 365, note 44.

[5] A *lêwî* (for *lâwî*) is a *môrêh;* Arab. *álwâ* is equivalent to Heb. *hôrâh*. In Exodus, iv., 14; Judges, xvii., 7 *lêwî* evidently means *priest*. For *bêth* before *bath lêwî* see Haupt, *The Book of Esther* (Chicago, 1908) page 18, line 6.

exclusive worship of the Sun.[6] He prohibited the cult of Amon and of all other gods; their images were destroyed, and their names erased from the walls of the temples and other public buildings. After his death, however, a reaction set in, and his innovations were abolished.[7] But some priests of this monotheistic cult may have survived in Heliopolis, and Moses's father-in-law may have been one of them.

Hobab is not a proper name, but a term for *father-in-law.*[8] Jethro, the *hôbáb* of Moses, was attached to the Edomite clan Reuel. JHVH was an Edomite god. The meaning of the name is *He who causes to be.* In Exodus, iii, 14 we must read instead of the meaningless *ehyêh ashér ehyêh,* I am that I am: *ahyêh ashér ihyêh,*[9] I cause to be what is.[10] The old name of this god of the Edomites was *Esau,* which is a dialectic form of the Hebrew word *'Osêh* (for *'âsai*) Maker. The Jews are the descendants of the Edomite worshipers of JHVH,[11] who were united under the leadership of David about 1000 B. C. David belonged to the Edomite clan Ephrath in one of the fertile valleys about Hebron. He was not a native of Bethlehem, neither was any son or descendant of David ever born at Bethlehem.

[6] An uncle of Amenophis IV. was high-priest in Heliopolis; see *Zeitschrift der Deutschen Morgenländischen Gesellschaft,* vol. lxiii., page 247, line 29. Userkaf, the first king of the Fifth Dynasty, is said to have been high-priest of Heliopolis prior to his accession to the throne (about 2680 B. C.). Compare below, page 368, note 59.

[7] Compare the notes on the translation of *Joshua,* in the Polychrome Bible, page 49.

[8] In the Targum Jerushalmi ii. we find (Deuteronomy, xxvii., 13) the feminine *ḥabîbthâ,* lit. the beloved, for the Heb. *ḥôthénth.* mother-in-law.

[9] The pronunciation *yihyêh* is incorrect. We say *Israel,* not *Yisrael.* Contrast the dissertation of Erich Ebeling, *Das Verbum der el-Amarna-Briefe* (Berlin, 1909) page 10.

[10] This would be in Assyrian: *ušábšâ ša ibášû;* in Arabic: *ukáuwinu mâ yakûnu.*

[11] The majority of them were Edomites, but they comprised also Horites, Canaanites, Ishmaelites, Moabites, Hittites, Amorites, Philistines, Egyptians, and Ethiopians, *i. e.,* a mixture of Asiatic, African, and European elements. For the Philistines compare the *Proceedings of the Society of Biblical Archæology,* vol. xxxi. (London, 1909) page 233. Even the Phenicians may have come from Europe. Herodotus, who states (i., 1; vii., 89) that the Phenicians were originally settled on the Red Sea, confounds the Phenicians with the Jews.

Judah (*Yĕhûdâh*) is not the name of an Israelitish tribe, but a feminine collective to *yĕhôdêh,* he confesses.[12] King of Judah is originally a title like the Islamic Commander of the Faithful. The worship of JHVH was introduced in Israel by David (about 1000 B. C.) after he had conquered the northern confederation of Israelitish tribes; but after the death of Solomon (about 930 B. C.) the Israelites relapsed into their former idolatry.[13] The Israelites have vanished; they survive only, mixed with numerous foreign elements, including a considerable percentage of Aryan colonists,[14] in the Samaritans whose number is now reduced to 170 souls.

The Israelites were not in Egypt, but the Edomite ancestors of the Jews were in Egypt (about 1230 B. C.) under the reign of Merneptah,[15] whose name appears in the Old Testament as Menephtoah.[16] At that time the Israelites were settled in Palestine,

[12] The relation between the participial form *môdêh,* confessor, and the old imperfect form *yĕhôdêh,* he confesses, is the same as the connection between the modern Jewish name *Meyer* (Heb. *Me'îr*) and the old name *Jair* (Heb. *Ya'îr*) which appears in the New Testament as *Jairus.*

[13] Compare the translation of Joshua, xxiv., 2. 14. 23, in the Polychrome Bible, and the Notes, page 91, lines 3–6; also Genesis, xxxv., 2; xxxi., 19.

[14] In the second half of the eighth century B. C. the Assyrian kings sent Babylonian colonists from Babylon and Cutha to Samaria; they also transferred there Aryan colonists from Hammath and other Galilean cities; see *Orientalistische Literaturzeitung,* vol. xi., columns 237–239.

[15] Canon Cheyne notes in his *Encyclopædia Biblica,* col. 1182, below, that thirty years ago Mr. Baker Greene (*Hebrew Migration,* pp. 37. 117. 199. 310) brought the passage in the Anastasi papyrus (vi., 4, 14, where a high official asks permission for the entrance into Egypt of tribes from the land of Aduma) into connection with the settlement of Hebrew tribes, such as the Josephites and, as he thought, the Kenites.—The Josephites, however, were not in Egypt. The ancestors of the Israelites came from the pasture grounds south of Haran in Mesopotamia, and invaded Palestine from the northeast; whereas the ancestors of the Jews, who had sojourned in Egypt, came from Elath, at the northeastern end of the Red Sea, and invaded Palestine from the south. The Israelites settled in Palestine about B. C. 1400; the Jews came about the end of the eleventh century. Compare below, page 366, line 8.

[16] Heb. *ma'yân mê nephtôḥ* (Joshua, xv., 9; xviii., 15) does not mean *The fountain of the waters of Nephtoah,* but *The Fountain of Me(r)neptah.* The modern name of this place is *Liftâ.* In this village, about two miles northwest of Jerusalem, there is a large fountain, the waters of which are collected in a great walled reservoir of very early origin. The locality is undoubtedly ancient. See Cheyne's *Encyclopædia Biblica,* col. 3394.

in the region of Mount Ephraim. At the time of Gideon (about 1100 B. C.) the Israelitish peasants in Palestine were idolaters, while the invading Midianites were worshipers of JHVH. The legends of the ancient Israelites have been subsequently conformed to Judaic standards, just as the traditions of South Arabia have been systematically altered by the followers of Mohammed. The names of the ancient Israelitish gods in the old legends were afterwards replaced by the "Angel of JHVH"[17] or JHVH.[18] Gideon's name *Jerubbaal*[19] shows that he was not a worshiper of JHVH.

If the Midianite bedouins had not been defeated by the Israelitish peasants, they would have conquered Palestine from the east. As they were repulsed at that time, they afterwards invaded Palestine from the south.

It is possible that in the time of Gideon the son of an Israelitish herdsman was sold by Midianitish Ishmaelites (or Ishmaelitish Midianites)[20] as a slave into Egypt, where he afterwards attained a prominent position. But the statement that this happened to the ancestor of Ephraim and Manasseh is a later modification of the original tradition. As the Israelites never were in Egypt, the official historians tried to create the impression that Ephraim and Manasseh had been born in Egypt, and that the Israelites had been from the beginning worshipers of JHVH. The story of Joseph seems to have been influenced in some respects by the ancient Egyptian poetic autobiography of Sinuhet (about 2000 B. C.).

Liftâ = *Nephtah;* change of *l* and *n* is not exceptional: the modern name of the Biblical *Shunem* is *Sûlem;* on the other hand, *Bethel* is now known as *Beitîn,* and *Jezreel* as *Zer'în.* Talmudic *tarnĕgôl,* rooster, is the Sumerian *dar-lugallu,* king of the variegated birds (chickens). Compare J. Hunger, *Babyl. Tieromina* (Berlin, 1909) p. 42.

[17] Wellhausen remarks in the notes on the translation of the Psalms, in the Polychrome Bible, page 176, line 36: Judaism has turned the heathen gods into angels, commissioned by JHVH to govern the various nations.

[18] Compare, *e. g.,* Genesis, xxxi., 11. 13; also xvi., 11. 13; Judges, vi., 11.

[19] The name *Jerubbaal* means Baal requites, rewards. The Hebrew verb *rûb* or *rîb,* to strive, to sue, means originally *to retaliate, to try to obtain redress.* It has recently been shown that we have the same verb in the name of Sennacherib, Assyr. *Šin-aḫe-rîbâ,* O Moongod give brothers as a reward! Gideon's god was *Baal-bĕrîth* (Judges, viii., 33) *i. e.,* the Baal of Oracular Decision. Also *sefr hab-bĕrîth* (Exodus, xxiv., 7) means not the Book of the Covenant, but The Book of (Oracular) Decision(s).

[20] Compare Judges, viii., 24; Genesis, xxxvii., 25-28.

Also Balaam was a prophet of JHVH, while the Israelites, who were to be cursed by this Edomite seer, were idolaters. In Numbers xxiii., 7 we read that Balaam came from Aram, from the great mountain[21] in the east, *i. e.*, Mount Sinai in the neighborhood of Elath, on the northeastern shore of the Red Sea. This *Aram* is not Syria, but the Koranic *Iramu* which we find in the 89th sura in connection with the Adites. *Iramu* (or *Aramu*) denotes the region southeast of Elath. Balaam is identical with Lokman the Wise. *Loḳmân* is a translation of *Balaam.*[22] Both names mean *Devourer.* The name of Balaam's father is *Be'ôr,* and Lokman's father was called *Ba'ûr.* Lokman was born at Elath; *êlâth* or *êlôth* means *tall trees,* including palms, and there is a large grove of palm-trees near Elath. In Judges, i., 16 Elath is called The City of Palm-trees.

In the Koran the Midianites of Elath are called *aç̣hâbu-'l-aikati,* the People of the Grove. *Aikat* is an adaptation of Ailat, the Arabic name of Elath. Just as Midian is not a tribal name, but the ancient term for the Sinaitic amphictyony, so the Adites, referred to in the Koran, are not a tribe, but a religious confederation. Arab. *'âd* is the collective to *'âdah,* custom, usage, institution, a synonym of *súnnah* which may be connected with Sinai; it is originally a designation of the Worshipers of JHVH, as are also Midian and Jehudah, the prototypes of the later Congregation (Heb. *kahál* and *'edâh*). Hûd, the name of the prophet who was sent to the Adites, is but a shortened form of Jehudah. Shu'aib, the Arabic name of Jethro, means *small tribe.*[23]

[21] The mountains = the great mountain; compare the notes on the translation of *Ezekiel,* in the Polychrome Bible, page 157, line 22.

[22] Similarly *Nazareth* is a translation of the older name of this Galilean town, *Hinnathon* or *Hittalon,* mispointed *Hannathon* and *Hethlon,* which means *Seclusion;* see my paper *The Ethnology of Galilee* in the *Transactions of the Third International Congress for the History of Religions* (Oxford, 1908) vol. i., page 303, line 3. The original form of the name Nazareth may have been *Naçârath* with final *t* as in Zarephath = Sarepta (Assyr. *Çariptu*).

[23] Compare Heb. *mĕthê mispár,* or *mĕthê mĕ'áṭ,* or *ha-mĕ'áṭ mikkól hâ-'ammîm* (Genesis, xxxiv., 30; Deuteronomy, iv., 27; vii., 7; xxvi., 5; Psalm, cv., 12). For the Adites compare the new *Enzyklopædie des Islam,* edited by Houtsma and Schade, page 128.

Mount Sinai, the sacred mountain of Midian, must have been a volcano. When the Edomite ancestors of the Jews came to Mount Sinai after the exodus from Egypt, there were thunders[24] and lightnings, and a thick cloud upon the mount, and the voice of the trumpet exceeding loud. . . And Mount Sinai was altogether on a smoke . . . and the smoke thereof ascended as the smoke of a furnace, and the whole mount quaked greatly. This passage (Exodus, xix., 16. 18) describes a volcanic eruption accompanied by earthquakes and thunderstorms. The voice of the trumpet (or rather ram's horn)[25] denotes the subterraneous roaring, rumbling, and thundering accompanying a volcanic eruption or earthquake. Homer (*Il.* xxi., 388) uses ***trumpeting*** for ***thundering***.[26] We use ***blare*** not only of a sound like that of a trumpet, but also of a loud or bellowing noise. We speak of the ***blare of trumpets*** and the ***blare of thunder***. In Babylonian omen tablets the blare of thunder is compared to the voices of various animals: rams, asses, horses, hogs, lions, dogs, rats, chickens and other birds, etc.[27] Pliny (ii., 193) says that earthquakes are preceded or accompanied by a terrible noise which resembles either a murmuring, or a roaring, or the shouting of men, or the clangor of arms (*praecedit vero comitaturque terribilis sonus, alias murmuri similis, alias mugitibus aut clamori humano armorumque fragori*). A Winchester physician said of the recent seismic shocks in Virginia at the beginning of this month (April, 1909): I felt two earthquake shocks. They were like the boom of heavy cannon fired in quick succession, and were followed by a loud roaring and rumbling. The earth trembled, and my house swayed perceptibly.

In the same way the walls of Jericho, which were excavated a

[24] Lit. *voices;* the plural is intensive; compare above, page 360, note 21. Thunder was regarded as the voice of God.

[25] See the cuts in the Appendix on the Music of the Ancient Hebrews in the translation of the *Psalms,* in the Polychrome Bible, page 222; compare the translation of *Joshua,* page 63.

[26] Compare also the various uses of Lat. *fremitus, sonitus, strepitus;* Greek κλαγγή, κτύπος, βρόμος, etc. See my paper on the Trumpets of Jericho in the Vienna Oriental Journal, 1909.

[27] See J. Hunger, *Babylonische Tieromina nebst griechisch-römischen Parallelen* (Berlin, 1909) page 168.

year ago by the *Deutsche Orient-Gesellschaft*,[28] were destroyed by an earthquake accompanied by shouting and horn-blowing, *i. e.*, roaring and rumbling. The idea that the walls of this ancient impregnable fortress fell down owing to the shouts of the Israelites and the horn-blowing Israelitish priests[29] is a later embellishment.

Similarly, Sodom and Gomorrah were destroyed by a tectònic earthquake. This was discussed more than ten years ago by the German geologist Blanckenhorn, in his book on the Dead Sea and the Destruction of Sodom and Gomorrah (Berlin, 1908).[30] Also the explanation of the Pillar of Salt was given long ago. At the southwestern end of the Dead Sea there is the so-called Mountain of Sodom, consisting of crystallized rock-salt. From the face of it great fragments are occasionally detached by the action of the rains, and appear as pillars of salt, advanced in front of the general mass. Such pillars (or pinnacles) have been often noticed by travelers. Lieutenant W. F. Lynch described one which was about 40 feet high, cylindrical in form, and resting on a kind of oval

[28] See No. 39 of the *Mitteilungen der Deutschen Orient-Gesellschaft* (Berlin, 1909).

[29] Compare the translation of the sixth chapter of the Book of Joshua in the Polychrome Bible and the Notes, on page 62. The *failing* of the waters of the Jordan, as described in Joshua, iii., 16 (compare the Notes on page 60) may have been due to a landslip some 16 miles north of Jericho, near *Ed-Dâmieh* (the ancient *Adam*, or rather *Adamah*, south of the mouth of the Jabbok) where the valley of the Jordan contracts to a narrow gorge. Canon Cheyne states in his *Encyclopædia Biblica*, col. 2400, that minor landslides still occur in that region, and a large one might again dam up the Jordan, and let it run off into the Dead Sea, leaving the bed temporarily dry. An Arabic historian relates that on Dec. 7, A. D. 1266, in the neighborhood of *Ed-Dâmieh*, a lofty mound, which overlooked the river on the west, fell into the water and dammed it up for several hours.

[30] Compare Diener, *Die Katastrophe von Sodom und Gomorrha im Lichte geologischer Forschung* in the *Mittheilungen der K. K. Geographischen Gesellschaft in Wien*, 1897, pp. 1–22; also Cheyne's *Encyclopædia Biblica*, col. 1047. For the fire (Genesis, xix., 24. 28) following the earthquake, note Genesis, xiv., 3. 10 (the region was full of *slimepits*, i. e., *bitumen springs*). *From the Lord out of heaven* (Genesis, xix., 24) is a subsequent addition; *rained* does not necessarily mean that the *brimstone and fire* came out of heaven; compare Psalm lxxviii., 27. The *Cologne Gazette* of April 27, 1909, reported that during the recent earthquake at Lisbon, on April 23, 1909, boiling water, smoke, and sulphureous dust were ejected from several large fissures.—There are sulphur springs in the region of the Dead Sea.

pedestal, some 50 feet above the level of the sea. A picture of it is given in Lynch's *Narrative of the U. S. Expedition to the River Jordan and the Dead Sea* (Philadelphia, 1850) page 308.[31] Canon Driver, of Christ Church, Oxford, says (in Hastings's *Dictionary of the Bible*): It is probable that some such pillar, conspicuous in antiquity, gave rise to the story of Lot's wife. The late Professor Edward Robinson, of Union Theological Seminary, New York, remarked in his *Biblical Researches* (vol. ii., page 108) that during the rainy season such pillars were constantly in the process of formation and destruction.

The other day my little girl, who is but 12 years old, was reading some of the numerous clippings which denounced my allusion to the destruction of Sodom and Gomorrah and raised the question how I could explain the Pillar of Salt.[32] She said, How could Lot see that his wife became a pillar of salt? If he had looked back, he would have become a pillar of salt. The meaning of the original text in Genesis, xix., 26 is undoubtedly that as soon as Lot's wife looked back, she became a pillar of salt. In a Philadelphia paper a correspondent stated, I had overlooked the comma. There were no commas in the original text. The majority of the readers of the Bible do not realize that the title-page of the Authorized Version contains the statement *translated out of the original tongues and with the former translations diligently compared and revised, by His Majesty's special command.*

In Exodus, xxiv., 17 we read: The sight of the glory of JHVH was like devouring fire[33] on the top of the mount in the eyes of the Israelites. According to Exodus, xiii., 21, JHVH was before them by day in a pillar of a cloud, and by night in a pillar of fire.[34] The modification that this pillar of smoke or fire preceded them on their march in the wilderness is a later embellishment suggested by

[31] Compare my paper on Jonah's Whale in the *Proceedings of the American Philosophical Society,* vol. xlvi., page 162, note 3.

[32] I alluded to it in a paper on the location of Mount Sinai, which I read at the annual meeting of the American Oriental Society, New York, April 16, 1909.

[33] Compare also Deuteronomy, iv., 24. 36; ix., 3; Psalm, xcvii., 3; Hebrews, xii., 29.

[34] Compare Genesis, xv., 17.

the custom of carrying at the head of a caravan, in a cresset mounted upon a long pole, a beacon-fire, the blaze of which served as a guiding-light at night, while the smoke signaled the direction during the day. According to the Priestly Code (which was compiled by Jewish priests during the Babylonian Captivity about 500 B. C.) the cloud was over the Tabernacle by day, and by night fire beaconed there.[35] But originally the cloud was on the top of Mount Sinai, and at night it had a fiery aspect.

Sinai means *covered with senna shrubs.*[36] This seems to be the older name of the Mountain of JHVH. Horeb, which is equivalent to *Mont Pelé,* i. e., *Bare Mountain,*[37] is a later name.[38] The top of the mountain may have been bare after the eruption observed by the Hebrews after their exodus from Egypt.[39] The volcano may have been dormant for centuries[40] when Moses saw the first flame of fire out of the midst of the bush, *i. e.,* a clump of senna shrubs.

The famous Arabian geographer and historian Abulfedâ (who died in A. D. 1331) says: Opinions differ with regard to Mount Sinai. Some say, It is a mountain in the neighborhood of Elath; others, A mountain in Syria. According to some, *sînâ* denotes the stones of the mountain; according to others, the shrubs thereon.[41] *Sanâ'* is the Arabic name for *senna,* and *sînâ* means *small stones,* i. e., the *lapilli* of the volcano. In Exodus, xix., 13 the Hebrews are warned

[35] See Haupt, *The Book of Canticles* (Chicago, 1902) page 22 = *The American Journal of Semitic Languages,* vol. xviii., page 212; compare Haupt, *Biblische Liebeslieder* (Leipzig, 1907) page 22.

[36] *Cassia angustifolia.* This shrub, which is more than six feet high, is found on the shore of the Red Sea. The best senna leaves (*folia sennae*) come from Arabia.

[37] Horeb may also be interpreted to mean *making bare* or *Destroyer* (Arabic *ḫârib*).

[38] In several passages (Exodus, iii., 1; xvii., 6; xxxiii., 6; i. Kings, xix., 8) Horeb represents a later addition. The name Horeb does not occur before the 7th century B. C.

[39] The top of Mount Etna, which is now bare, was wooded in the sixteenth century.

[40] Mount Vesuvius seemed to be extinct from 1500 to 1631; it was covered with trees and shrubs, the cattle browsed within the crater; but on Dec. 16, 1631, there was a terrific eruption which destroyed some 3,000 men.

[41] The Arabic text (p. 69 of the Paris edition) reads: *wa-ṭûru Sînâ'a 'ḫtálafû fîhi, fa-qîla: huwa jábalun bi-qúrbi Ailata, fa-qîla: sînâ'u ḥijâratuhu, w̆a-qîla: šájarun fîhi.* Mount Sinai is called also *ṭûru Sînîna.*

against drawing too near to the mountain, inasmuch as any man or beast might be killed by a volcanic bomb or the lapilli ejected from the volcano. The universal interpretation of this passage (which we find also in the New Testament, Hebrews xii., 20) that men or beasts that disregarded this prohibition were to be executed by being stoned or shot with an arrow, is grotesque. No Hebrew ever shot a domestic cow with an arrow.

There is a mountain in the neighborhood of Elath, known as the *Jabal an-Nûr,* the Mountain of Light, or *Jabal al-Barghîr,* a modification of *barghîl,* which denotes a region near the water or between cultivated land and the wilderness. The Arabs say that the Lord spoke to Moses on that mountain. There is also a *Jabal Ḥarb,*[42] southeast of Elath, which is 7,218 feet high. It is situated near the eastern shore of the Red Sea, about lat. 28° N., west of Tabûk, north of Ziba on the Red Sea, on the route of the pilgrims from Egypt to Mecca. We ought to send an expedition to Akaba to find out whether these two mountains are extinct volcanoes and covered with senna shrubs.[43] Systematic explorations of this volcanic region of the cradle of Judaism would no doubt yield most striking results.

I am inclined to think that not only the Edomite ancestors of the Jews came from that region, but also the Semites who invaded both Babylonia and Egypt. The aborigines of Egypt must have been a negroid race,[44] but Semites must have invaded the valley of the Nile in the prehistoric period. Some of these Semitic invaders,

[42] My attention has been called to the fact that A. H. McNeile, *The Book of Exodus* (London, 1908) p. cv. states: Horeb must . . . be located . . . on the east of the Gulf [of Akaba]. And it is worthy of notice that in modern maps a Jabal Ḥarb is situated on the east of the Gulf, a little south of lat. 28°.

[43] We ought to disinter also the ancient capital of Galilee, at the hot springs (*Ḥammâth*) south of Tiberias, and the traditional home of Abraham, Ur of the Chaldees, the present *Mughair.* I have been advocating excavations at Mughair for more than 25 years. Dr. John P. Peters states in his work on *Nippur* (vol. ii., page 300): I have seen no mound which seemed easier and safer to excavate, or promised richer results than Mughair.

[44] See my paper *The Aryan Ancestry of Jesus,* page 9, note *; compare the *Zeitschrift der Deutschen Morgenländischen Gesellschaft,* vol. lxiii., page 250, lines 24–30. See also above, page 356, note 4.

it may be supposed, came over land, across the isthmus of Suez, and founded the northern kingdom of Egypt in the Delta. Others came across the Red Sea, near Koṣeir,[45] and established the Southern Kingdom in Upper Egypt. The northern and the southern kingdoms were afterwards united by Menes, about B. C. 3300, just as David united his southern kingdom with the northern kingdom of Israel about 1000 B. C.

The Israelites may have originally lived with their Edomite brethren on the northeastern shore of the Red Sea, but they must afterwards have sojourned for some time in Mesopotamia[46] before they settled in Palestine. They may be a branch of the Semites who had invaded Northern Babylonia and had afterwards gone to Assyria.[47] The Edomite ancestors of the Jews invaded Palestine from the south prior to B. C. 1000, but the Israelites must have come to Palestine from the northeast (probably through Raḳḳah on the Euphrates, Palmyra, and Damascus)[48] prior to B. C. 1400, and settled first in the northern region of the country east of the Jordan, *i. e.*, Bashan and Gilead.[49] If the Israelites sojourned in Mesopotamia, we can understand the points of contact between the Israelitish law-book[50] in Exodus, xxi., 2—xxii., 17 and the Code of Hammurapi (B. C. 1958–1916).[51] The Decalogue (Exodus, xx., 1–17) repre-

[45] On the western bank of the Nile, at Nakâdah and al-Ballâs, about five days' journey from Koṣeir, there are some of the earliest settlements in Egypt. Compare also the *Proceedings of the Society of Biblical Archæology*, vol. xxxi. (London, 1909) page 210, line 4.

[46] Probably on the pasture-grounds south of Haran, between the Euphrates and the Chaboras. Compare above, page 358, note 15, and Genesis, xi., 28. 31; xxiv., 4. 10; xxvii., 43; xxviii., 2; xxxi., 18; xxxiii., 18; Deuteronomy, xxvi., 5. The Hebrew term for Mesopotamia, *Arâm-Naharâim*, means *The Arameans of the Great River*, i. e., the Euphrates; see Haupt, *The Book of Nahum* (Baltimore, 1907) page 31.

[47] In Genesis, x., 11 the Authorized Version renders correctly in the margin: *he went out into Assyria.*

[48] Raḳḳah means *bank, shore;* Palmyra = Tadmor (for Titmur): *palmy, abounding in palms;* and Damascus seems to be a contraction of *Dâr-mašḳî* well-watered region. See my paper on the Ethnology of Galilee (cited above, page 360, note 22) and the *Zeitschrift der Deutschen Morgenländischen Gesellschaft*, vol. xli., page 195, line 9; also *Orientalistische Literaturzeitung*, vol. x., col. 306; vol. xii., col. 214, note 15.

[49] Compare Genesis, xxxi., 21. 47; Deuteronomy, i., 4, etc.

[50] Compare above, page 359, note 19. [51] See next page.

sents the quintessence of the old moral and religious precepts,[52] which was probably extracted by the prophets[53] in the seventh century, after Israel had fallen in B. C. 721, and which was afterwards still more concentrated by Jesus.[54]

According to later Judaic tradition, Abraham came from Ur of the Chaldees, and went afterwards to Egypt (Genesis, xii., 10). The same source states that Abraham had an Egyptian concubine (Genesis, xvi., 1^b). The object of such statements as we find, *e. g.*, in Genesis, xliii., 32, is to emphasize the fact that the Egyptians, among whom the Edomite ancestors of the Jews sojourned for some time, considered themselves superior to the forefathers of the Israelites. Genesis, xxvii., 36 (compare xxv., 33) explains how it happened that the Israelites in the north possessed a higher civilization than their Edomite brethren in the south. The Israelites were peasants; the Edomites, on the other hand, semi-nomadic shepherds. Sons of Leah means *cowboys;* Sons of Rachel, *shepherds.*[55] The statement that Joseph, the father of Ephraim and Manasseh, was a Son of Rachel, must be viewed in the same light as the tradition that the Israelites were in Egypt (compare above, page 359, line 19).

The ancient Egyptians called themselves Worshipers of Horus, the god of light. This deity may be ultimately identical with the god of the Sinaitic volcano. *Ḥarr* is the Arabic term for volcanic regions. In the Old Testament we find *ḥarerîm* in Jeremiah, xvii., 6. Nahor, which was originally the name of an Aramaic deity, can hardly be connected with Horus.[56]

[52] Compare the *Johns Hopkins University Circulars,* No. 163 (June, 1903) page 59; A. H. McNeile, *The Book of Exodus* (London, 1908) page xlvii; Ed. Meyer, *Geschichte der Altertums,* vol. i., part 2 (Stuttgart, 1909) page 450.

[53] Compare Exodus, xxii., 17–xxiii., 19.

[54] See my paper *The Religion of the Hebrew Prophets* in the *Transactions of the Third International Congress for the History of Religions* (Oxford, 1908) vol. i., p. 270.

[54] See Matthew, xxii., 40; vii., 12; compare Romans, xiii., 9.

[55] Heb. *leah* = cow, *rachel* = ewe. See my paper on Leah and Rachel in the *Zeitschrift für die alttestamentliche Wissenschaft,* Vol. xxxix. (Giessen, 1909), pp. 281–286.

[56] For Horus in Old Testament names see Cheyne's *Encyclopædia Biblica,* col. 3304, § 81.

Every statement with regard to prehistoric periods is, of course, more or less conjectural. But I adhere to the principle that the probably right is preferable to the undoubtedly wrong. The possibility cannot be denied. It is even possible that the Sumerians are Egyptian emigrants of the pre-Semitic population of Egypt, who left their native land after the double Semitic invasion across the isthmus of Suez and the Red Sea near Ḳoṣeir. The Sumerians may have come from Egypt to Southern Babylonia through the Persian Gulf. This would explain the legend of Oannes[57] and several remarkable points of contact between Egyptian culture and Babylonian civilization. There is even a racial resemblance between the Sumerian heads of Telloh and the head of the famous statue of the Egyptian scribe in the Louvre or the head of the well-known wooden statue known as the ***sheikh al-balad***.[58]

We have, of course, no mathematical evidence for the prehistoric periods of Arabia, Egypt, and Babylonia. But so much is certain: Jewish monotheism is derived from Egypt,[59] and the sacred mountain of the Edomite ancestors of the Jews was a volcano near the ancient Edomitic port of Elath at the northeastern end of the Red Sea. The Burning Bush on the Mountain of God as well as the miraculous passage of the Hebrews through the Red Sea[60] are not legendary, but historical.

[57] See Zimmern's remarks in E. Schrader, *Die Keilinschriften und das Alte Testament* (Berlin, 1903) page 535.

[58] See the plates in Ed. Meyer, *Sumerier und Semiten* (Berlin, 1906) and *Aegypten zur Zeit der Pyramidenerbauer* (Leipzig, 1908).

[59] We can trace the beginning of the solar monotheism of ancient Egyptian theology to the Fifth Dynasty (2680-2540 B.C.). Horus was gradually superseded by Ra, just as JHVH was substituted for Esau. Compare above, page 357, note 6.

[60] The Edomite ancestors of the Jews may have crossed the Red Sea at the small peninsula, 75 miles (120 kilometers) south of the northern end of the modern Suez Canal, between the larger and the smaller basins of the Bitter Lakes which formed at that time the northern end of the Red Sea. Major-General Tulloch observed that under a strong east wind the waters of Lake Menzâlah, at the northern end of the Suez Canal receded for a distance of several miles. In the same way the water northeast of this peninsula may have been driven by a strong east wind (Exodus, xiv., 21) into the larger basin of the Bitter Lakes, while the water in the shallow lower basin receded at low tide. Although the Bitter Lakes and the Red Sea are now connected

I believe that the Deliverer was a historical person. But we need not believe that Moses and Aaron, Nadab and Abihu, and seventy of the elders of Israel saw God (Exodus, xxiv., 10). The author of the Fourth Gospel says (John, i., 18): No man hath seen God at any time. Deuteronomy, iv., 12, states: The Lord spake unto you out of the midst of the fire; ye heard the voice of the words, but saw no similitude; only ye heard a voice. But Jesus told the Jews according to St. John, v., 37: Ye have neither heard His voice at any time, nor seen His shape.

only by the modern Suez Canal, the tide extends to the southern end of the Bitter Lakes. The present northern end of the Gulf of Suez is practically dry at low tide. *Pi-hahiroth* (Exodus, xiv., 2) should be read *Pi-haherith, i. e.,* the mouth (*pî*) of the canal (*ha-ḥêrîth* = Assyr. *ḫerîtu*) connecting Lake Timsâḥ (north of the Bitter Lakes) with the Nile. See my papers on the crossing of the Red Sea and the palm-grove on the Red Sea in Peiser's *Orientalistische Literaturzeitung,* vol. xii. (Leipzig, 1909) columns 245 and 250. Further details concerning the statements made in the present paper may be found *ibid.,* in my articles on the birth-place of David and Christ; the ancestors of the Jews; Hobab, father-in-law; the name JHVH (cols. 65, 162, 164, 211) and especially in my paper on Midian and Sinai, pp. 506–530 of vol. lxiii. (Leipzig, 1909) of the *Zeitschrift der Deutschen Morgenländischen Gesellschaft.*

THE VERTEBRATES OF THE CAYUGA LAKE BASIN, N. Y.

(From the Department of Neurology and Vertebrate Zoölogy, Cornell University.)

WITH FOUR MAPS.

BY HUGH D. REED AND ALBERT H. WRIGHT.

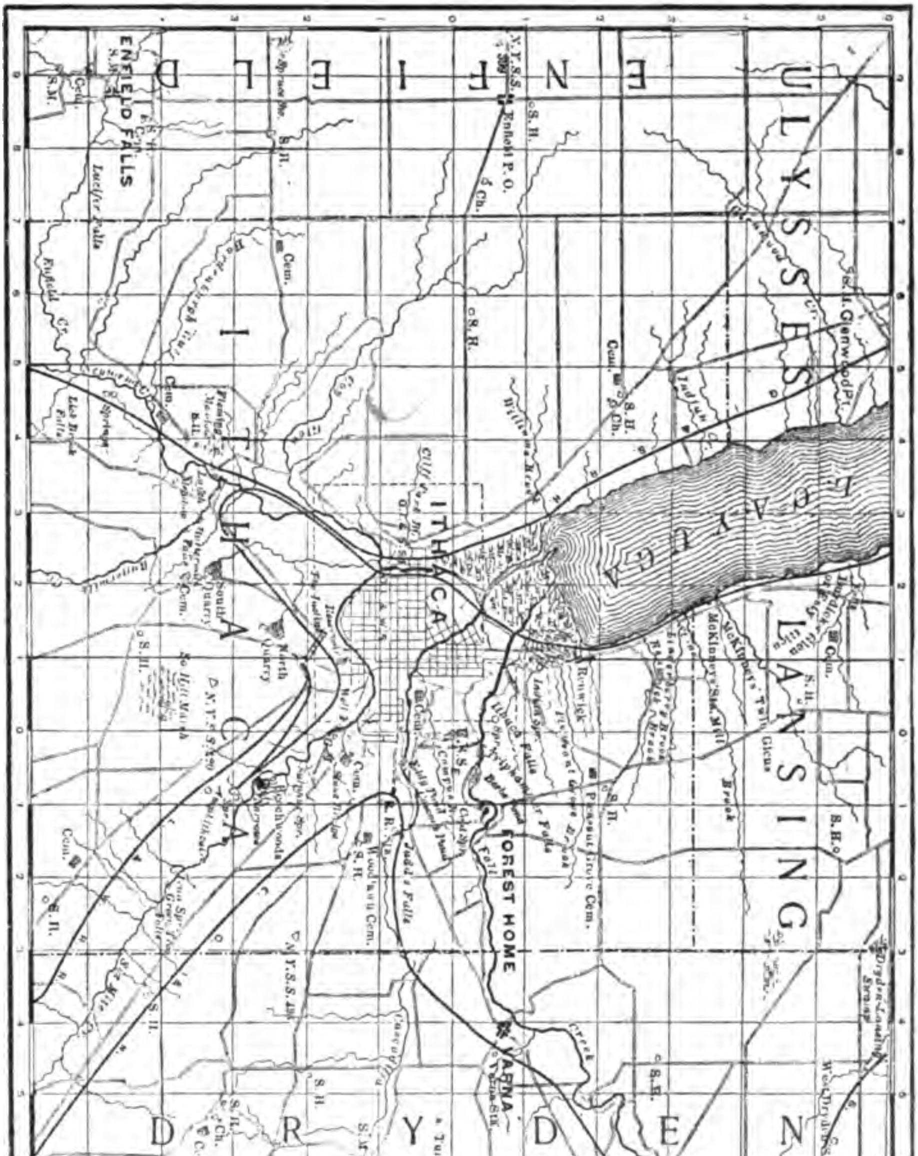
(*Read October 1, 1909.*)

INTRODUCTION.

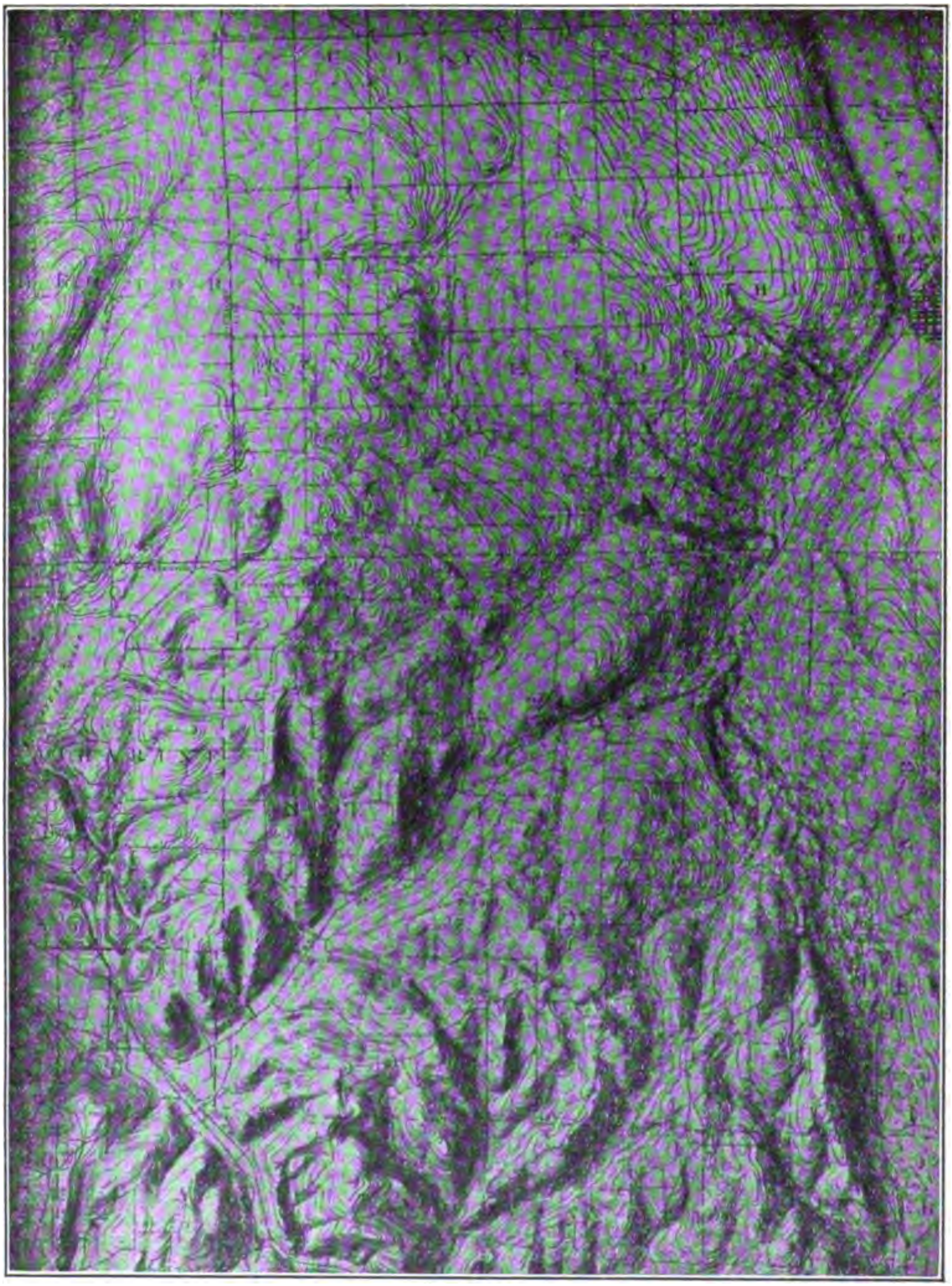
This paper is based mainly upon the records made by members of this department since the opening of the university in 1868; our personal observations have extended over the last twelve years. For valuable notes, helpful criticism and material assistance we are indebted to Professors B. G. Wilder, T. L. Hankinson and E. H. Eaton and to Messrs. G. S. Miller, Jr., L. A. Fuertes, A. A. Allen, G. C. Embody and John Vann. Many others have aided in various ways and acknowledgments are made in the proper places.

The paper includes all the vertebrates known by us to occur in this basin. Each record is based upon specimens taken within our limits. In cases of doubt as to identification the specimens have been submitted to specialists in the group.

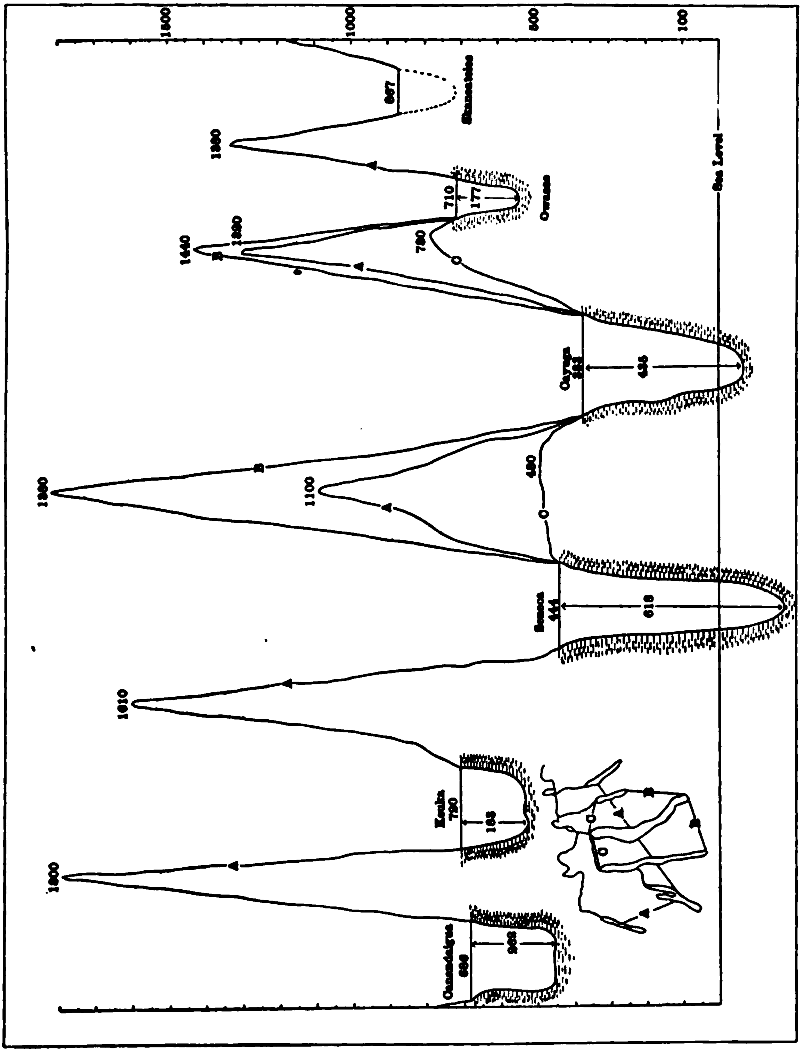
The only previous publications which deal specifically with the vertebrates of this region are: " Fishes of Cayuga Lake," by B. G. Wilder, published in the Weekly Ithacan for June 25, 1875, " Notes on the Fishes of Cayuga Lake Basin," by Seth E. Meek, published in the *Annals of the New York Academy of Sciences,* Vol. IV., 1899, and " The Lake and Brook Lampreys of New York, Especially those of Seneca and Cayuga Lakes," by S. H. Gage, in the " Wilder Quarter-Century Book," 1893. There are numerous other publications which contain notes upon the vertebrates of this basin, particularly the birds and reptiles, to which reference will be made elsewhere.



Map of Ithaca and Vicinity.



Relief Map of the Ithaca Quadrangle.



Cross-section of the Finger Lake Region.

The Maps.—The map of the Ithaca region (Pl. XVII) is from Dudley's "The Cayuga Flora." It shows this region in more detail than the general map. A small portion of the southern end of the basin is shown in a photograph (Pl. XVIII) of a relief map made by William Stranahan from the U. S. Geological Survey sheets. It gives a very accurate idea of the gorges and general surface carving in the southern portion of the basin. It is through the courtesy of Mr. Stranahan and the authorities of the Cornell University Library that we are able to reproduce it here. Plate XIX represents a cross-section of the finger-lake region, showing the comparative depths and altitudes of lake levels and the altitude of intervening land. The lakes are represented in section at their deepest points, the land as indicated by the lines *A, B, C* on the figure in the lower left-hand corner of the plate. The distance between the lakes is not proportional to the elevation. Plate XX is a map of the lake region of central New York based primarily upon the map published by Professor Dudley in his flora of the basin. It has been modified in many particulars in order to adapt it to the needs of the present paper. The modifications are based largely upon the maps of the U. S. Geological Survey and in a minor degree upon personal observations. The number accompanying the name of a town or hill indicates its altitude above sea level. The altitudes are taken from bench marks so far as they are given. In other cases the altitude given is that of the contour which passes through the center of a town or indicates the top of a hill.

The Lake Basin.—Cayuga is the largest of a series of approximately parallel lakes in central New York which extend in a north and south direction. They are long and narrow, virtually deep river valleys, and consequently have been very appropriately designated the "Finger Lakes." The basin as delimited in this paper (Pl. XX) comprises about 1,600 square miles. Throughout the greater part of this area only the actual catchment basin has been included, but, in the northern portion, the limits as we have set them are, to a certain degree, arbitrary. It includes a portion of the Clyde and Seneca rivers and the large Montezuma marshes which cover an area of 45 square miles.

The greatest length of the basin is about 65 miles, extending

from the source of Butler Creek southward to the source of the Cayuga inlet near North Spencer. The width gradually increases from 12 miles at Montezuma to Taughannock Falls, where it suddenly broadens to about 30 miles because of a finger-like extension along the course of Fall Creek.

The length of the lake is usually estimated at thirty-eight miles, its breadth from one and a half to three miles. In appearance, therefore, it resembles a great river; indeed it is said to occupy a part of a preglacial river channel of which the Neguaena[1] valley was the continuation. The height of the lake above mean tide is 383[2] feet, the greatest depth found by numerous soundings of the Cornell University Engineering Department was 435 feet at a point directly off Kidder's Ferry. In the section between Myers Point and Sheldrake Point it is in many places over 400 feet deep. On account of its depth its waters are comparatively cold far into the summer, and rarely become so chilled in winter as to admit of the formation of ice over the deeper sections. From one half to two thirds of the middle section usually remains open, but in the winter of 1884–5 the lake was frozen over before the middle of February and the ice did not break up till the first week in April. There is a tradition that this occurs about once in twenty years (Dudley).[3]

Data collected from various sources show that this tradition has some foundation in fact. Since the beginning of white settlements in this basin, soon after the Revolutionary War, the lake has frozen over seven times and the intervals have been, with one exception, from eighteen to twenty years. During the winter of 1836, ice covered the lake throughout its extent but was apparently very thin, for in an article under the caption "Cayuga"[4] written in 1846 the writer observed that this condition lasted for a day or two only. Prior to 1836, the lake had been frozen twice but nothing is known concerning the dates further than that the intervals were about twenty years—probably about 1816 and 1796. During March and April, 1856, ice ten inches thick closed the entire lake. At many points teams were driven across. The *Ithaca Weekly Journal* of March 12, 1856, contains the following note:

Cayuga Lake is frozen over completely from one extreme to the other. The like has not been known for over twenty years (1836):

[1] Now called the Inlet valley.

[2] The average level as given by the U. S. Geological Survey is 381 feet.

[3] Dudley, William R., "The Cayuga Flora, Part I.: A Catalogue of the Phænogamia Growing without Cultivation in the Cayuga Lake Basin," *Bulletin of the Cornell University* (Science), Vol. II., 1886, Andrus and Church. Ithaca, N. Y.

[4] *Ithaca Daily Chronicle*, Dec. 22, 1846, Vol. I., no. 140.

During the last half of February and the first of March, 1875, ice thirteen inches thick covered the entire lake. On February 15, 1884, the lake again froze over completely and remained so until April 4. Since this date Cayuga has frozen from end to end but once and then during February, 1904. In certain places the ice was 22 inches thick. The shallow water at either end of the lake is frozen over usually by the middle of December and remains in this condition until the middle of March or the first of April.

Dudley further observes:

> The temperature of the lake unquestionably influences the development of vegetation in its immediate vicinity. Plants on its shores are usually a week later in the spring than in the neighboring ravines and the warm valley about Ithaca, and a week earlier than on the distant hills; and during the first half of November, the blue flowers of *Aster lævis* and the white plumes of *Aster sagittifolius* still remain in considerable abundance, while they have long ago matured and faded near Ithaca.
>
> Proceeding southward from the gently sloping shores near Cayuga Bridge the banks become gradually bolder, until in the vicinity of Levanna the first cliffs appear on the eastern shore. Between Willets and Kings Ferry these reach their culmination in the "High Cliffs"; but stretches of lofty, precipitous, or more or less broken declivities occur on both shores until within a few miles of the southern extremity. At intervals, especially near the mouth of some stream, are low, half-sandy points which yield many rare plants. Near Ithaca, and about two miles from the lake, the great valley forks, the main portion continuing to the right of South Hill, a preglacial valley of erosion extending southwardly to Waverly in the Susquehanna Valley. The other portion on the left of South Hill is similar to the first and forms the present Six Mile Creek and White Church Valleys, and opens into the Susquehanna at Owego. These deep valleys penetrate and cut through the great dividing ridge between the St. Lawrence or Great Lake hydrographic system to which our streams and smaller lakes are tributary, and the Susquehanna system, and are parallel to similar valleys east and west of us. The headwaters of the streams occupying them, *i. e.*, the summits between the two systems are usually very near the crossing of the dividing ridge. (Dudley.)

Hydrographic Areas.—A glance at a hydrographic map of the state will reveal the existence of seven river systems, only two of which lie within the province of this paper, namely: the Oswego, of which the Finger Lakes are a part, and the Susquehanna. The latter has in New York a catchment area of 6,267 square miles and comes into very close relation with the Oswego system through the numerous inlets of the Finger Lakes where the origins of many

of the streams of each system are very close, in a few instances with actual water connection.

The close relation existing between the Finger Lakes and the Susquehanna system is most marked in the tributaries of Cayuga Lake. Sixmile and Wilseyville creeks arise about three miles apart with a considerable elevation intervening, but within the upper three miles of their respective courses, they approach within three fifths of a mile of each other at precisely the same level with no high land between. Buttermilk creek arises one fourth of a mile from Michigan creek and three tenths of a mile from Danby Creek, all at an elevation of 1,100 feet. Taughannock Creek arises in the same marsh with a tributary of Cayuta Lake at an elevation of 1,300 feet. The inlet of Cayuga Lake arises one and one half miles from Spencer Creek at the same elevation and in the same stretch of marshy area. The west branch of the Inlet at its source is one fifth of a mile from Cantor creek in Pony Hollow. Sixmile Creek and the west branch of the Owego Creek rise in the same marsh at an altitude of 1,280 feet. The west branch of the Owego Creek also comes into close relation with Fall Creek through the tributaries of Dryden Lake.

These examples serve to show not only the possibility of recent connections but in the case of several streams of the two systems an actual connection at the present time. The sources of Sixmile and Wilseyville creeks are so close that they are connected for limited periods during flood times. Professor R. S. Tarr has expressed to us the belief that before the region was settled and the dense virgin forests cleared away, many of the streams of the Cayuga and Susquehanna systems, with present close relations, were actually connected in the heavily wooded swamps.

The outlet of the Finger Lakes is the Seneca River, which constitutes the principal component of the Oswego system. The stream itself is about fifty miles long and according to the U. S. Geological Survey has a drop of only twenty feet which accounts for its sluggish, meandering and marshy course. It receives the drainage of a little more than three thousand square miles of territory.

The following is a table of the elevations, and area of water and of catchment basins of the Finger Lakes taken from Rafter:[5]

Lake.	Elevation in Feet.	Area of Water in Square Miles.	Area of Catchment Basin in Square Miles.
Canandaigua	686	18.6	175
Keuka	720	20.3	187
Seneca	444	66.0	707
Cayuga	381	66.8	1593
Owasco	710	12.4	208
Skaneateles	867	12.8	73
Otisco	784	3.0	34

Thus it appears that Cayuga has a slightly greater water area,[6] a decidedly greater catchment basin and a lower level (Pl. XIX) than any of the other Finger Lakes. The catchment basin is larger than the combined basins of the other six lakes. The usual fluctuation between high and low water in Cayuga is not great. Upon this point Rafter observes (p. 112):

According to figures given in the Eleventh Annual Report of the State Board of Health of New York it appears that the maximum fluctuation of Cayuga Lake for a long series of years has been 7.56 feet, although this large fluctuation may be possibly partly due to work done by the state in cutting out the channel of the Seneca River for the purpose of draining the Montezuma marsh. Ordinarily, the fluctuation of Cayuga Lake does not exceed between 2 and 3 feet. From March 4, 1887, to December 2 of that year, the lake fell 2.93 feet. By way of illustrating how these great natural reservoirs tend to prevent floods, it may be mentioned that the configuration of Cayuga outlet with relation to Clyde River is such that frequently, when there are heavy rainfalls in the catchment area of the Clyde River, Cayuga Lake being at the same time at a low level, the entire flood flow of Clyde River is discharged into Cayuga Lake without affecting Seneca River below the mouth of the Clyde River at all. It is undoubtedly due to this fact that fall floods on Oswego River are almost entirely unknown.

The evaporation of the Oswego River catchment area is exceedingly large—about 28 inches—whence it results that the run-off from a mean annual rainfall of from 36 to 37 inches does not exceed about 9 or 10 inches.

During the winter of 1908–9 the lake level fell 1.25 feet below the mean level (383 feet), the lowest it had been for twenty years.

[5] Rafter, George W., "Hydrology of the State of New York," Bull. 85 of the New York State Museum, 1905, p. 216.

[6] Much greater if the forty-five square miles of the Montezuma marshes are included.

The principal tributaries of Cayuga Lake are: Cayuga Inlet, Six-mile Creek, Cascadilla Creek, with a combined catchment area of 173 square miles, Salmon Creek, with a catchment area of 90 square miles, and Taughannock Creek, with a catchment area of 60 square miles. In their upper courses all these streams follow broad and gently sloping preglacial valleys without waterfalls. All, however, except the inlet, have cut a mile or more of post-glacial channel just before entering the lake valley. Here the channels are narrow and deep and the descent sudden, forming the gorges and waterfalls so characteristic of the tributaries of Seneca and Cayuga lakes. The fall of these streams in the last two miles (more or less) is between four and five hundred feet. What is said here of the principal tributaries applies to most of the streams entering Cayuga lake. In this connection Professor Dudley wrote:

> There remains but one other feature to mention in this general review. Nothing in the physical aspect of this region strikes the stranger as more characteristic than the so-called gorges or ravines found in the first great bench above the lake and valleys, wherever a creek or even a brook descends to the lower level. The true gorges are probably, without exception, of recent or post-glacial origin; the walls are frequently of perpendicular or overhanging rock from fifty to two hundred feet or even much higher, as in Taughannock and Enfield ravines. Within these great chasms are usually falls or cascades, some of them exceedingly beautiful and of considerable height.

The Life Zones.—The Cayuga Lake basin is, in the main, typically Transitional, although in certain localities there is a trace of the Upper Austral and Canadian. All of the nine species of mammals, which, Miller[7] observes, "will serve to identify any part of the Transition zone in New York," are found within the basin. These forms are:

Southeastern red squirrel,	*Sciurus hudsonicus loquax.*
Southern flying squirrel,	*Sciuropterus volans volans.*
Northern pine mouse,	*Microtus pinetorum scalopsoides.*
Naked-tailed mole,	*Scalops aquaticus.*
Hairy-tailed mole,	*Parascalops breweri.*
Northeastern chipmunk,	*Tamias striatus lysteri.*
Bonaparte's weasel,	*Putorius cicognani.*
Big brown bat,	*Vespertilio fuscus.*

[7] Miller, Gerrit S., Jr., "Preliminary List of New York Mammals," Bull. of the New York State Museum, Vol. VI., No. 29, 1899.

Of the eastern birds which find their northern breeding limit in the Transition zone, nineteen out of the twenty-two mentioned by Miller breed in this basin. They are:

Bob-white,	*Colinus virginianus.*
Ruffed grouse,	*Bonasa umbellus umbellus.*
Mourning dove,	*Zenaidura macroura carolinensis.*
Yellow-billed cuckoo,	*Coccyzus americanus.*
Whip-poor-will,	*Antrostomus vociferus.*
Least flycatcher,	*Empidonax minimus.*
Baltimore oriole,	*Icterus galbula.*
Towhee,	*Pipilo erythrophthalmus.*
Grasshopper sparrow,	*Ammodramus savannarum australis.*
Indigo bunting,	*Passerina cyanea.*
Rough-winged swallow,	*Stelgidopteryx serripennis.*
Northern loggerhead shrike,	*Lanius ludovicianus migrans.*
Yellow warbler,	*Dendroica æstiva.*
Parula warbler,	*Compsothlypis americana usneæ,*
Long-billed marsh wren,	*Telmatodytes palustris.*
Catbird,	*Dumetella carolinensis.*
Brown thrasher,	*Toxostoma rufum.*
Wood thrush,	*Hylocichla mustelina.*
Blue bird,	*Sialia sialis.*

Of the ten eastern birds which find the southern limit of their breeding range in the Transition zone of New York, six breed in this basin:

Pied-billed grebe,	*Tachybaptus podiceps.*
Purple finch,	*Carpodacus purpureus.*
Nashville warbler,	*Vermivora rubricapilla.*
Chestnut-sided warbler,	*Dendroica pensylvanica.*
Chickadee,	*Penthestes atricapillus.*
Veery,	*Hylocichla fuscescens.*

In the higher hills and in the upper parts of the gorges at the south end of the basin there is an unmistakable tinge of the Cana-

dian zone. In these localities are found five of the ten Canadian mammals characteristic of this zone in New York. They are:

Canadian white-footed mouse,	*Peromycus maniculatus gracilis.*
Common red-backed mouse,	*Evotomys gapperi gapperi.*
Woodland jumping-mouse,	*Napæozapus insignis.*
Northeastern mink,	*Putorius vison vison.*
Smoky shrew,	*Sorex fumeus.*

Of the sixteen more characteristic Canadian birds breeding in New York, the Blackburnian and Magnolia warblers breed upon these hills. Associated with this assemblage of Canadian forms are others which, while not characteristically Canadian, may be considered northern forms. Such are:

Slate-colored junco,	*Junco hyemalis.*
Nashville warbler,	*Vermivora rubricapilla.*
Black-throated blue warbler,	*Dendroica cærulescens.*
Black-throated green warbler,	*Dendroica virens.*
Water-thrush,	*Seiurus noveboracensis.*
Canadian warbler,	*Wilsonia canadensis.*
Winter wren,	*Nannus hiemalis.*
Hermit thrush,	*Hylocichla guttata pallasii.*

In about the same degree in which a trace of the Canadian zone is found in the higher portions of the basin there is a trace of the Upper Austral in the lowlands about the head and outlet of the lake. In these places are found such of the characteristic birds of the Upper Austral zone as breed in New York, viz.,

Louisiana water-thrush,	*Seiurus motacilla.*
Yellow-breasted chat,	*Icteria virens.*
Hooded warbler,	*Wilsonia citrina.*
Carolina wren,	*Thryothorus ludovicianus.*
Tufted titmouse,	*Bæolophus bicolor* (one specimen).

In the same localities with the above are found species which reach their northern breeding limit in the Transition zone in New York having a wider breeding range to the southward, viz.:

Barn owl,	*Aluco pratincola.*

Red-bellied woodpecker,	*Centurus carolinus.*
Rough-winged swallow,	*Stelgidopteryx serripennis.*
Orchard oriole,	*Icterus spurius.*

A few Lower Austral forms, as the glossy ibis, the egret and the turkey vulture, have been taken in Montezuma marshes during the summer season. In the lowlands about the head of the lake, particularly the Renwick marshes, there remain throughout the winter a number of transients and summer residents. They are:

Kingfisher,	*Ceryle alcyon.*
Flicker,	*Colaptes auritus luteus.*
Meadow lark,	*Sturnella magna.*
Song sparrow,	*Melospiza melodia.*
Swamp sparrow,	*Melospiza georgiana.*
Winter wren,	*Nannus hiemalis.*
Long-billed marsh wren,	*Telmatodytes palustris.*
Robin,	*Planesticus migratoria.*

The localities where the more southern birds are found breeding and where a few summer residents pass the winter are the alluvial flood plains which constitute the "sheltered spots" of the basin. According to Dudley a few very rare plants belong to these levels, among them the more southern species.

Meteorology.—The basins of Canandaigua, Keuka, Seneca and Cayuga lakes constitute a meteorological subdivision of the state termed the Central Lake region. On the north this subdivision meets the Ontario region. Lakes Owasco and Skaneateles are considered as within the meteorological subdivision known as the Eastern Plateau which lies to the east and southeast of the central lakes. The Seneca lake basin, except for a small portion of its northern extremity, lies wholly within the Central Lake region while that of Cayuga is not only continuous with the Ontario region in its northern extremity but its southeastern portion projects for a considerable distance into the Eastern Plateau.

The normal annual temperature of the Central Lake region differs only slightly from that of the Ontario and to the extent of about three degrees only from the Eastern Plateau. The normal temperature for each of the three regions computed from the nor-

mal annual temperatures for eleven years, 1891–1901, is: Ontario 47.5°, Central Lakes 48.3°, Eastern Plateau 45.9°. Thus it appears that the Central Lake region is .8° warmer than the Ontario and 2.4° warmer than the Eastern Plateau.

The extent to which the lake modifies the climate of the basin, if any, is still to be determined. Dr. W. D. Wilson, of Geneva, in comparing the influence of the lakes upon Ithaca and Geneva,[8] states that the northerly winds in winter are warmed by their passage up the lake valley, which they follow more or less closely, and cause the temperature in the vicinity of Ithaca during this season to stand 3.3 degrees higher than it otherwise would. According to E. C. Turner the observations made at Ithaca prior to 1897 substantiate Dr. Wilson's views and moreover indicate that they apply to the whole of the central lake region.

The normal monthly temperature for Ithaca compiled from data collected from 1875 to 1905 follows:

January	24.1	July	70.6
February	25.1	August	68.2
March	31.9	September	60.6
April	44.2	October	49.5
May	57.0	November	37.6
June	66.2	December	28.4

The sum of daily heat units above 32 degrees is 14,317, compiled from a table of normal daily temperature for 33 years and the average normal daily temperature of the six hottest weeks is 70.4 degrees. According to Turner, from 1879 to 1893 the average date of the latest freezing temperature was May 6, the extremes being April 9 and May 29. The average date of the first freezing temperature in the fall was October 10, the earliest being September 26, while in one year 32 degrees was not reached until October 31. A table of the latest spring and earliest fall killing frosts from 1900 to 1907 at three stations in the basin follows:

	Ithaca.	Romulus.	Auburn.
1900.	May 7–Oct. 20	May 10–Oct. 20	May 6–Oct. 16
1901.	April 12–Oct. 28	Oct. 18	April 12–Oct. 6

[8] See Turner, E. T., Eighth Annual Report of the New York Weather Bureau, Assembly Documents, Vol. 25, 1897, p. 440.

	Ithaca.	Romulus.	Auburn.
1902.	May 10–Oct. 10	May 15–Oct. 15	May 14–Oct. 10
1903.	May 2–Oct. 25	May 2–Oct. 25	May 2–Oct. 24
1904.	May 12–Oct. 7	April 22–Sept. 22	April 22–Sept. 22
1905.	May 2–Oct. 26	May 3–Oct. 26	May 2–Oct. 23
1906.	May 21–Oct. 1	May 21–Oct. 8	May 21–Oct. 8
1907.	May 12–Oct. 21	May 21–Oct. 9	May 21–Oct. 9

The average precipitation for the Central Lake region is slightly less than that for either the Great Lake or Eastern Plateau. The mean annual precipitation for these regions compiled from precipitation data for the years 1891 to 1902 is: Great Lakes 35.65 inches, Eastern Plateau 40.8 inches, Central Lakes 34.46 inches. The normal monthly precipitation at Ithaca compiled from the last twenty-nine years follows:

January	2.16 in.	July	3.75 in.
February	1.87 in.	August	3.24 in.
March	2.44 in.	September	2.83 in.
April	2.29 in.	October	3.17 in.
May	3.43 in.	November	2.58 in.
June	3.88 in.	December	2.64 in.

From 1900 to 1907 there have been from 150 to 185 rainy days each year. For the same period the annual snowfall (unmelted) has varied from 46.4 to 75.8 inches, the average being 63.6. One of the striking features of the region about Ithaca is the small percentage of clear days, as the following table will show:

	Cloudy.	Partly Cloudy.	Clear.	Percentage of Clear Days.
1900	174	109	82	22.4
1901	171	126	68	18.6
1902	149	151	65	17.8
1903	195	98	72	19.7
1904	180	115	71	19.4
1905	148	126	91	24.9
1906	164	92	109	29.8
1907	163	140	62	16.9

Based upon average hours of sunshine from 1900 to 1903 R. G. Allen derived 49 per cent. as an annual mean of sunshine, or a monthly mean of 189 hours of sunshine.

The average of mean relative humidities at Ithaca from 1900 to

1907 is 77 per cent., based upon readings taken at 8 A.M. The range for these years being from 73 to 80 per cent.

The total movement of wind in miles varies from 62,556 to 79,172. The maximum velocity ranges from 36 to 54 miles per hour in the period from November to March. The prevailing direction of the wind for the past eight years has been northwest. Besides the general winds there are local currents or night winds particularly in the southern portion of the basin. Concerning these Dr. W. M. Wilson[9] writes:

The night wind commonly sets in two or three hours after sunset, first as a light breeze, but gradually increasing in strength until a velocity of about eight miles per hour is reached. This current has its origin on the hillsides at the southern end of the lake and flows northward down the channels of the two principal streams which form the inlet, converging into the main depression at the head of the lake. The flow of the current as it moves northward over the level surface of the lake is augmented by the cool currents which join the main stream through the numerous gorges and water courses entering the valley from either side. Along the western shore at the southern end of the lake, where the densely wooded slopes cool the air near the surface, the flow of the cool breeze down the water courses towards the lake often continues throughout the day. The night breeze is usually stronger, but the day breeze as it comes from the depths of the woods is delightfully refreshing.

The meteorological conditions of the Cayuga basin and more particularly those about Ithaca are thus commented upon by Garriott:[10]

In spring, summer and autumn precipitation is preceded twelve to forty-eight hours by southeast winds and falling barometer, and the barometer generally falls to 29.90, or below, in spring and summer, and to 29.95, or below, in autumn before precipitation begins. In winter southerly winds precede precipitation, but the winds shift more quickly and the signs of precipitation are not so well defined as in other seasons; precipitation begins in this season with a falling barometer and when the barometer has fallen to 30 or below. On account of the position of this station on the hillside and above the lake, diurnal winds are noticeable, especially during the warm months. When not influenced by passing storms these winds come as a gentle east to southeast breeze by night and by day a northwest wind having a velocity of two or three times greater than the day breeze. When, instead of shifting to the

[9] Wilson, W. M., "New York Section of the Climatical Service of the Weather Bureau in coöperation with Cornell University," August, 1906, p. 59.

[10] Garriott, Edward B., "Weather Folk-lore and Local Weather Signs," U. S. Department of Agriculture, Bull. 294 of the Weather Bureau, p. 93.

northwest in the early morning, the wind continues from the southeast and begins to increase in force, the approach of a storm is indicated. While rain begins most frequently with falling barometer, the heaviest rainfall often comes, especially in the warmer months, after the turn of the barometer from falling to rising.

Richard's registering hygrometer shows that in spring and summer the humidity sometimes decreases before rain, but rapidly increases after rain begins; in spring rain begins with relative humidity from 50 to 98 per cent., and in summer it may be as low as 50 per cent. one hour before rain begins. In autumn the effect of day and night seems greater than the influence of passing storms, and rain will begin with relative humidity as low as 50 per cent. one hour before rain. In winter there is usually an increase in humidity from one half to four hours before rain, and dry snow will begin with relative humidity as low as 40 per cent.

Cirrus clouds are reliable indications of precipitation in all seasons, but are liable to be obscured by lower clouds of local formation in the colder portion of the year. These clouds appear moving from the west in the spring and winter, from the northwest in summer, and from the southwest in autumn, twenty-four to thirty-six hours before precipitation begins. Special characteristics of clouds have not been noted except in connection with cirrus clouds.

Frost is likely to damage fruit or other crops in May and September. Heavy frost is generally preceded by high barometer, low temperature and humidity, very high wind and clear weather.

The Fishes of the Basin.—The fish fauna of the basin comprises 65 species distributed among 21 families, as follows:

Petromyzonidæ	2	species.	Umbridæ	1	species.
Acipenseridæ	1	"	Esocidæ	2	"
Lepisosteidæ	1	"	Pœciliidæ	1	"
Amiidæ	1	"	Gasterosteidæ	1	"
Siluridæ	5	"	Percopsidæ	1	"
Catostomidæ	4	"	Atherinidæ	1	"
Cyprinidæ	19	"	Centrarchidæ	7	"
Anguillidæ	1	"	Percidæ	7	"
Clupeidæ	1	"	Serranidæ	1	"
Salmonidæ	5	"	Cottidæ	2	"
Gadidæ	1	species.			

As yet too little is known of the fish fauna of the finger lakes to draw any definite conclusions concerning the general distribution of species or the relation of these faunas to others. Lake Cayuga and Seneca River have water connection with Lake Erie and the Hudson River through the Erie Canal; with Lake Ontario both through river and canal (Oswego); with the Susquehanna system through several

of the southern tributaries at certain periods of the year. It is possible, therefore, that these lakes may receive species from all three sources. Of the 65 species found in the basin 19 are common to the Ontario and Susquehanna basins although frequently varying in abundance. A table follows:

	Susquehanna.	Cayuga.	Ontario,
Exoglossum maxillingua,	very common,	common,	uncommon.
Semotilus bullaris,	very common,	rare,	uncommon.
Erimyzon sucetta oblongus,	very common,	uncommon,	uncommon.
Esox reticulatus,	common,	common,	rare.
Catostomus nigricans,	very common,	rare,	common.
Hybopsis kentuckiensis,	common,	rare,	common.
Chrosomus erythrogaster,	common,	rare,	uncommon.
Percina caprodes zebra,	common,	rare,	common.
Lota maculosa,	rare,	uncommon,	common.

Several of the basses are common to all three basins but the introduction of these species from one place to another renders them of no comparative value.

Twenty-one species are common to the Cayuga and Ontario basins. Two species, *Cottus gracilis* and *Notropis procne,* are common to the Cayuga and Susquehanna basins. There are in the Cayuga basin four species which do not occur in either the Ontario or Susquehanna. One of these is the smelt, *Argyrosomus osmeriformis,* confined to the interior lakes of New York. The others, *Notropis umbratilis, Notropis anogenus* and *Lepomis cyanellus,* are most common in the northern portion of the basin and doubtless found their way hither through the Erie Canal from Lake Erie.

It appears that the fish fauna of the Cayuga basin bears the stamp of Lake Ontario with just a trace of the Susquehanna and Erie basins. There is a possibility that species which seem to have found their way here from the Erie and Susquehanna basins were introduced along with game fishes or from bait pails. Observations made in Monroe Co., New York, by A. H. Wright[11] indicate that fishes find their way eastward through the Erie Canal.

Amphibia.—One of the characteristic features of our vertebrate fauna is the relative abundance of amphibian species and individuals, particularly in the southern portion of the basin. In this respect the

[11] Wright, A. H., MS., "The Fishes of Monroe Co., New York."

basin is similar to the mountains of Pennsylvania. The seventeen species are distributed among the following families:

Proteidæ	1 species.	Pleurodelidæ	1 species.
Ambystomidæ	1 "	Bufonidæ	1 "
Plethodontidæ	5 "	Hylidæ	2 "
Desmognathidæ	1 "	Ranidæ	5 "

Reptilia.—Twenty species of reptiles are known within our limits. The lizards are represented by a single specimen of the Ground Lizard, *Leiolopisma laterale,* found just northeast of Caroline on the divide between Sixmile Creek and a branch of the Susquehanna. Twelve species of snakes are known, three of which are now very rare. The rattlesnake so far as we know is met with only occasionally in the region about McLean, while the blacksnake and pilot snake are confined to the extreme southern portion of the basin near Newfield and Danby.

There are seven species of turtles, representing four families as follows:

Trionychidæ	1 species.	Kinosternidæ	1 species.
Chelydridæ	1 "	Emydidæ	4 "

Only three of the seven species, the snapping turtle (*Chelydra serpentina*), Agassiz's painted turtle (*Chrysemys marginata*), and the wood tortoise (*Clemmys insculpta*) are found distributed throughout the basin. The other four are confined to the extreme northern portion. The musk turtle (*Terrapene odorata*), a species fairly widely distributed east of the Mississippi, was first found in this basin in the fall of 1908 and proved to be common in the Seneca River near the Erie Canal. The Soft-shelled turtle (*Aspidonectes spinifer*), a species of more northern and western distribution, is very rare at the south end of the basin but found fairly common about Montezuma. The Speckled tortoise (*Clemmys guttata*) is widely distributed in central and eastern United States but in this region is confined to the vicinity of the Junius Ponds north and west of Waterloo. Muhlenberg's turtle (*Clemmys muhlenbergii*), a species limited in its range to eastern Pennsylvania, New Jersey and the Hudson Valley, is the only more eastern form found here aside from those of wide distribution.

Birds.—The birds that have been recorded for this region comprise 257 species distributed among 51 families as follows:

Colymbidæ	3 species.	Strigidæ	8 species.
Gaviidæ	2 "	Cuculidæ	2 "
Alcidæ	1 "	Alcidinidæ	1 "
Laridæ	9 "	Picidæ	7 "
Procellariidæ	1 "	Caprimulgidæ	2 "
Phalacrocoracidæ	2 "	Micropodidæ	1 "
Pelecanidæ	1 "	Trochilidæ	1 "
Anatidæ	33 "	Tyrannidæ	8 "
Ibididæ	1 "	Alaudidæ	2 "
Ardeidæ	6 "	Corvidæ	3 "
Gruidæ	1 "	Icteridæ	8 "
Rallidæ	6 "	Fringillidæ	31 "
Phalaropodidæ	3 "	Tanagridæ	1 "
Recurvirostridæ	1 "	Hirundinidæ	6 "
Scolopacidæ	20 "	Bombycillidæ	1 "
Charadriidæ	4 "	Laniidæ	2 "
Aphrizidæ	1 "	Vireonidæ	5 "
Odontophoridæ	1 "	Mniotiltidæ	31 "
Tetraonidæ	1 "	Motacillidæ	1 "
Columbidæ	2 "	Mimidæ	2 "
Cathartidæ	1 "	Troglodytidæ	5 "
Buteonidæ	9 "	Certhiidæ	1 "
Falconidæ	3 "	Sittidæ	2 "
Pandionidæ	1 "	Paridæ	2 "
Aluconidæ	1 "	Sylviidæ	2 "
Turdidæ	9 species.		

The following tables show the seasonal status of each species that has been found in the lake basin.

Permanent Residents.

Bob-white,
Ruffed grouse,
Red-tailed hawk,
Red-shouldered hawk,
Barn owl,
Long-eared owl,
Short-eared owl,
Barred owl,
Screech owl,
Great horned owl,
Hairy woodpecker,
Downy woodpecker,
Red-headed woodpecker,
Prairie horned lark,
Blue jay,
Crow,
Goldfinch,
Song sparrow,
White-bellied nuthatch,
Chickadee.

Transient Visitants.

Holboell's grebe (sometimes in winter),
Horned grebe (sometimes in winter),
Common loon (sometimes in winter),
Bonaparte's gull,
Common tern,
Red-breasted merganser (a few regularly in winter),
Mallard (a few regularly in winter),
Gadwall,
Baldpate,
Green-winged teal,
Blue-winged teal,
Shoveller,
Pintail,
Lesser scaup duck (sometimes in winter),
Ring-necked duck,
Buffle-head (sometimes in winter),
Ruddy duck (sometimes in winter),
Great blue heron,
Black-crowned night heron,
Knot,
Pectoral sandpiper,
Least sandpiper,
Red-backed sandpiper,
Semipalmated sandpiper,
Sanderling,
Greater yellow-legs,
Yellow-legs,
Solitary sandpiper,
Black-bellied plover,
Semipalmated plover,
Broad-winged hawk (found breeding in 1890),
Duck hawk,
Pigeon hawk,
Osprey,
Yellow-bellied flycatcher,
Alder flycatcher (breeds locally),
Rusty blackbird,
Nelson's sparrow,
Acadian sharp-tailed sparrow,
White-crowned sparrow,
White-throated sparrow,
Junco (uncommon in winter; breeds locally),
Lincoln's sparrow,
Fox sparrow,
Northern loggerhead shrike,
Blue-headed vireo (found breeding in 1893),
Black and white warbler (breeds locally),
Nashville warbler (breeds locally),
Tennessee warbler,
Parula warbler (breeds locally),
Cape May warbler,
Black-throated blue warbler (breeds locally),
Myrtle warbler,
Magnolia warbler (breeds locally),
Cerulean warbler (breeds on Howland Island),

Bay-breasted warbler,
Black-poll warbler,
Blackburnian warbler (breeds locally),
Black-throated green warbler (breeds locally),
Pine warbler (breeds locally),
Palm warbler,
Water-thrush (breeds locally),
Connecticut warbler (fall only),
Mourning warbler (breeds locally),
Yellow-breasted chat (breeds locally),
Hooded warbler (breeds locally),
Wilson's warbler,
Canadian warbler (breeds locally),
Titlark,
Red-breasted nuthatch (sometimes in winter),
Golden-crowned kinglet (sometimes in winter),
Ruby-crowned kinglet,
Gray-cheeked thrush,
Olive-backed thrush (found breeding in 1890),
Hermit thrush (breeds locally).

Summer Residents.

Black duck (a few found regularly in winter),
Wood duck,
Bittern,
Least bittern,
Green heron,
King rail,
Virginia rail,
Sora,
Florida gallinule,
Coot,
Woodcock,
Wilson's snipe (not common at this season),
Spotted sandpiper,
Killdeer,
Mourning dove,
Marsh hawk,
Sharp-shinned hawk,
Cooper's hawk,
Bald eagle,
Sparrow hawk,
Yellow-billed cuckoo,
Black-billed cuckoo,
Belted kingfisher (sometimes in winter),
Yellow-bellied sapsucker (not common at this season),
Flicker (sometimes in winter),
Whip-poor-will,
Nighthawk,
Chimney swift,
Ruby-throated hummingbird,
Kingbird,
Phoebe,
Wood pewee,
Least flycatcher,
Bobolink,
Cowbird,
Red-winged blackbird (a few in winter),

Meadow lark (a few in winter),
Baltimore oriole,
Bronzed grackle,
Purple finch,
Vesper sparrow,
Savannah sparrow,
Grasshopper sparrow,
Chipping sparrow,
Field sparrow,
Swamp sparrow (sometimes in winter),
Towhee,
Rose-breasted grosbeak,
Indigo bunting,
Scarlet tanager,
Purple martin,
Cliff swallow,
Barn swallow,
Tree swallow,
Bank swallow,
Rough-winged swallow,
Cedar waxwing (irregularly in winter),
Red-eyed vireo,
Warbling vireo,
Yellow-throated vireo,
Chestnut-sided warbler,
Oven-bird,
Louisiana water-thrush,
Maryland yellow-throat,
Redstart,
Catbird,
Brown thrasher (uncommon at this season),
House wren,
Long-billed marsh wren,
Wood thrush,
Veery,
Robin (a few regularly in winter),
Bluebird.

Winter Residents.

Herring gull,
Merganser,
Redhead,
Canvasback,
Greater scaup duck,
Golden eye,
Old-squaw,
Scoter,
White-winged scoter,
Surf scoter,
Canada goose (more common as a transient),
Rough-legged hawk,
Pine grosbeak,
Red crossbill,
White-winged crossbill,
Redpoll,
Pine siskin,
Snow bunting,
Tree sparrow,
Northern shrike,
Winter wren (found breeding in 1878),
Brown creeper.

Of Rare Occurrence.

Red-throated loon (winter),
Brunnich's murre (winter),
Kittiwake (winter),
Iceland gull (winter),
Ring-billed gull (transient),
Fork-tailed gull (winter),
Least tern (transient),
Common cormorant (transient),
Double-crested cormorant (transient),
White pelican (transient),
Barrow's golden-eye (winter),
King eider (winter),
Greater snow goose (winter),
Brant (winter),
Whistling swan (transient),
Glossy ibis (summer),
Egret (summer),
Whooping crane (transient),
Yellow rail (transient),
Red phalarope (transient),
Northern phalarope (transient),
Wilson's phalarope (transient),
Dowitcher (transient),
Stilt sandpiper (transient),
White-rumped sandpiper (transient),
Hudsonian godwit (transient),
Willet (transient),
Long-billed curlew (transient),
Hudsonian curlew (transient),
Golden plover (transient),
Turnstone (transient),
Turkey vulture (summer),
Goshawk (winter),
Saw-whet owl (winter),
Snowy owl (winter),
Hawk owl (winter),
Arctic three-toed woodpecker (winter),
Red-bellied woodpecker (summer),
Olive-sided flycatcher (transient),
Orchard oriole (summer),
Lapland longspur (winter),
Leconte's sparrow (transient),
Dickcissel (summer),
Philadelphia vireo (transient),
Worm-eating warbler (transient),
Golden-winged warbler (summer),
Tufted titmouse (summer),
Orange-crowned warbler (transient),
Yellow palm warbler (transient),
Carolina wren (summer),
Short-billed marsh wren (transient),
Wheatear (fall),
Avocet (fall).

Accidental Visitants.

Black-capped petrel,
Blue goose,
Evening grosbeak,
European green-winged teal.

CATALOGUE OF SPECIES.

A. Class CYCLOSTOMATA.

I. Order HYPEROARTIA.

1. Family PETROMYZONIDÆ. The Lampreys.

1. **Petromyzon marinus unicolor** (De Kay). Lake lamprey.

Abundant in the lake, where they are very destructive to the larger fishes because of their parasitic habits.[12] They are found in great numbers in the lake inlet during the spawning season, which occurs between May 25 and the middle of June. There is, however, considerable variation in this respect according to the season. In 1900 the crest of the spawning season occurred during the last days of May. In 1902 active spawning continued until June 7, while in 1903 spawning was over entirely by June 1. Larvæ of various sizes are found at all seasons buried in the mud and sand bars below the spawning grounds. Transformation occurs from the last of August to the middle of October. The latest record of transforming individuals is that of three specimens taken October 16, 1907. In one of these transformation was just beginning. Judging from the different sizes of larvæ found at a given season the larval period is of about four years duration.

2. **Lampetra wilderi** Jordan and Evermann. Brook lamprey.

Common in the inlet, where they may be found in abundance during the spawning season, which occurs during the middle of May beginning, according to Professor Gage's observations, about the eighth of the month and lasting until about the twentieth. The maximum period averages near the middle of the month. This species is not parasitic at any stage in its life-history. It probably takes no food in the adult stage.

[12] See Gage, S. H., *op. cit.;* also Surface, H. A., "Removal of Lampreys from the Interior Waters of New York," Report of the New York Fisheries, Forest and Game Commission, 1898, pp. 191–243.

B. Class PISCES.

II. Order CHONDROSTEI.

2. Family ACIPENSERIDÆ. The Sturgeons.

3. **Acipenser rubicundus** Le Sueur. Lake sturgeon.
Rare.

A large specimen of this species, now in the collection of Cornell University, is reported as being from Cayuga Lake. Mr. Seth Green informs me that sturgeons have occasionally been taken in Cayuga Lake; but, so far as he knows, they have never been found in any other of the small lakes of central New York. I copy the following letter of recent date from Mr. H. V. Kipp, of Montezuma, N. Y.: "There have not been any sturgeons taken from Cayuga Lake since 1880, but quite a number before that date, and the largest known weighed 35 pounds." (Meek.)

On June 4, 1905, a specimen four feet long and weighing forty-two pounds was taken at Sheldrake by Dr. L. A. Gould and on December 3, 1908, a specimen (C. U. 5130) weighing fifty pounds was caught in the Seneca and Cayuga canal near Montezuma by William Ferrei and George Wildner. These are the only records of the sturgeon since Meek's list was published.

III. Order LEPIDOSTEI.

3. Family LEPISOSTEIDÆ. The Gars.

4. **Lepisosteus osseus** (Linnaeus). Long-nosed gar.

Rare. "Occasionally taken from the north end of the lake. Not as numerous as they used to be" (Meek). There are in the Cornell University Museum seven specimens taken at the south end of the lake as follows:

June 17, 1877, in the lower course of Fall Creek.

June 13, 1894, from shallow water at the head of the lake.

June 8, 1896, in Fall creek about one half of a mile from the mouth.

March 26, 1899, from the lake near Ithaca.

April 17, 1899, from the lake near Ithaca.

May 28, 1900, from shallow water at the head of the lake.

August 12, 1908, from the lake near Ithaca. Most of the specimens taken here are small, still showing the dark lateral band.

IV. Order HALECOMORPHI.

4. Family AMIIDÆ. The Bowfins.

5. **Amiatus calva** (Linnaeus). Bowfin.

Abundant. Meek recorded this species as "seldom taken near Ithaca" and "not common at the north end of the lake." During recent years the bowfin has increased so rapidly in numbers that it has become a serious pest. In shallow water during the month of August hundreds may be seen in rowing a quarter of a mile. Foster Parker, of Union Springs, reports that he has repeatedly seen them capture and swallow the young of marsh birds.

V. Order NEMATOGNATHI.

5. Family SILURIDÆ. The Catfishes.

6. **Ictalurus punctatus** (Rafinesque). Spotted catfish.

Rare. Only two specimens have been recorded; one eleven inches long was taken on hook and line near the mouth of the inlet by Mrs. R. J. Ashdown July 10, 1902; the other, ten inches long, was taken in the same locality August 25, 1908.

7. **Ameiurus natalis** (Le Sueur). Yellow cat.

There is one specimen (No. 888) in the collection of Cornell University taken from the lake September 27, 1877. This is probably the specimen referred to in Meek's list: "I have seen but one specimen of this species from the lake. It was taken a few years ago."

8. **Ameiurus vulgaris** (Thompson). Long-jawed cat.

The collection of Cornell University contains two specimens of this species taken from the lake; one November 7, 1885, the other February 16, 1886.

9. **Ameiurus nebulosus** (Le Sueur). Common bullhead.

Abundant in the lake and all of its tributaries. In the larger streams it is found above the falls.

10. **Schilbeodes gyrinus** (Mitchill). Tadpole cat.

Common throughout the lake along muddy shores and in the streams, below falls, over a muddy bottom.

VI. Order PLECTOSPONDYLI.

6. Family Catostomidæ. The Suckers.

11. **Catostomus commersonii** (Lacépède). Common white sucker.
Abundant throughout the basin both above and below falls.

12. **Catostomus nigricans** Le Sueur. Hog sucker.
There is a specimen in the U. S. National Museum from Cayuga lake. Mr. Richard Rathbun writes: "The specimen is among the Museum's earliest collections and is not accompanied by complete data."

13. **Erimyzon sucetta oblongus** (Mitchill). Chub sucker.
This species occurs throughout the lake although much more abundant at the north end.

14. **Moxostoma aureolum** (Le Sueur). Red horse.
Common at the north end of the lake and taken occasionally at the south end. Meek recorded this species as *M. macrolepidotum.* Specimens recently taken and the specimen in the collection of Cornell University are all clearly aureolum.

7. Family Cyprinidæ. The Minnows.

15. **Chrosomus erythrogaster** (Rafinesque). Red-bellied dace.
One specimen taken July 13, 1901, by T. L. Hankinson near Ithaca in a cold brook which is tributary to Fall Creek.

16. **Pimephales notatus** (Rafinesque). Blunt-nosed minnow.
Abundant at both ends of the lake and in the sluggish portions of the streams below the falls.

17. **Semotilus bullaris** (Rafinesque). Fall fish.
Two specimens have been recorded. One taken from the lake, January 24, 1891, and another from Beaver Brook near McLean May 21, 1902.

18. **Semotilus atromaculatus** (Mitchill). Creek chub.
Found throughout the basin as the most common minnow. In the streams above falls it is the most common fish.

19. **Abramis crysoleucas** (Mitchill). Roach.
Common in all sluggish waters over a muddy bottom. It has not been found above falls.

20. **Notropis anogenus** Forbes. Black-chinned minnow.

"Quite common in the canal near Montezuma" (Meek). It has been taken several times in fairly large numbers at the mouth of Fall Creek and in the lower course of Sixmile Creek.

21. **Notropis cayuga** Meek. Cayuga minnow.

Common in the lake and the lower course of tributaries. It has not been found above falls.

22. **Notropis heterodon** (Cope). Varying-toothed minnow.

Common in the south end of the lake and the lower courses of streams where the water is sluggish. It appears to be uncommon at the north end of the lake. The only record we have for that region is twenty specimens taken in the Canoga marshes, June 24, 1901. In 1885 J. H. Comstock and S. E. Meek took several specimens from Beaver Creek near McLean. This is the only record of its occurrence above the falls.

23. **Notropis blennius** (Girard). Straw-colored minnow.

Found only at the north end of the basin in sluggish water.

24. **Notropis procne** (Cope). Swallow-tailed minnow.

Not common. It has been taken several times in the lower courses of Sixmile and Renwick creeks.

25. **Notropis hudsonius** (De Witt Clinton). Spot-tailed minnow.

This species was found for the first time in this basin on April 25, 1908. It was taken in large numbers with a minnow seine in a slough at the Needham Biological Station in the Renwick marsh.

26. **Notropis whipplii** (Girard). Silverfin.

Common in the lower courses of all the streams at the south end of the basin. In the fall of 1903 several specimens were taken from Eddy pond in Cascadilla Creek above a series of falls which aggregate about 400 feet. This is the only place where the species has been found above falls. Its presence here is probably to be accounted for by the following: Mr. Wilbur Genung during the summer of 1903 stocked a mill pond, situated at the source of Cascadilla Creek, with fishes taken from an ice pond on the lowlands near Ithaca where this species is common. Specimens of this were undoubtedly among other species taken and later, when the dam

went out during a flood, found their way to Eddy pond between which and the site of the dam there are no falls.

27. **Notropis cornutus** (Mitchill). Red fin.

Abundant throughout the basin.

28. **Notropis atherinoides** Rafinesque. Rosy minnow.

Rare. Meek took one specimen in Sixmile Creek and a few at Montezuma. Two specimens were taken near the mouth of Fall Creek November 23, 1906, and another at the Needham Biological Station April 25, 1908.

29. **Notropis umbratilis lythrurus** Jordan. Blood-tailed minnow.

Meek records one specimen taken from a small stream near the Montezuma dry dock.

30. **Rhinichthys atronasus** (Mitchill). Black-nosed dace.

Common in the southern portion of the basin and as far north as Ludlowville. At present there is no evidence of its occurrence at the north end of the lake. It is found both above and below falls.

31. **Hybopsis kentuckiensis** (Rafinesque). Horny head.

The only record we have of this species is that of Meek: "A few specimens taken from Montezuma only."

32. **Exoglossum maxillingua** (Le Sueur). Cut-lip minnow.

Common. Found in all streams below falls in clear water.

33. **Cyprinus carpio** Linnaeus. Carp (introduced).

Abundant in the lake and in a few of the streams. This species was first noticed in the lake about 1889. Four or five years prior to this date three different persons had constructed ponds and stocked them with carp. One was at Newfield in a tributary to the inlet, a second was in a small tributary to Fall Creek six or seven miles from the lake and a third was at Ludlowville in a tributary of Salmon Creek. In 1888 all three of these ponds gave way during a heavy flood and in the following year carp began to be in evidence in the lake and have increased rapidly to the present time.

VII. Order APODES.

8. Family Anguillidæ. The True Eels.

34. **Anguilla chrysypa** Rafinesque. Common eel.

Common in the lake and the larger streams and ponds. The largest specimen taken in the basin of which we have any record is one caught in the lake May 29, 1893, which measured three feet in length. One caught off Kidder's Ferry a few years ago is said to have measured five feet.

VII. Order ISOSPONDYLI.

9. Family Clupeidæ. The Herrings.

35. **Pomolobus pseudoharengus** (Wilson). Alewife, saw-belly.

One of the most abundant fishes in the lake where it has been known since 1872. In the spring from the first of May to the middle of August they die in great numbers and are washed ashore. During the summer of 1907 dead individuals were much more abundant than in the three preceding years.

Many persons in the region of Cayuga lake attribute the presence of the alewife here to its introduction by Seth Green who, according to Dr. H. M. Smith,[13] disclaimed any responsibility for their presence in Lake Ontario, but we have been unable to find any statement concerning Cayuga Lake. Dr. T. H. Bean[14] is of the opinion that they have come hither of their own accord, for he writes:

> As to their presence in Seneca and Cayuga lakes, New York, we have ground for believing that they have, of their own accord, penetrated thus far into the interior of New York State. Mr. Fred Mather writes that he has seen alewives go up the canal locks at West Troy and Professor H. L. Smith, of Geneva, who first noticed them in the neighborhood of Seneca Lake in June, 1868, states that the canal was opened at about that time and thinks that they might come into the New York lakes from the Chesapeake or Delaware Bays through Elmira and Painted Post.

[13] Smith, H. M., "Report on the Fisheries of Lake Ontario," Bull. U. S. Fish Com., 1892, p. 188.

[14] Bean, T. H., "The Fisheries and Fishery Industries of the United States," Section I., Natural History of Aquatic Animals, Washington, 1884, p. 590. "Fishes of New York," Bull. 60, New York State Museum, p. 200.

Mr. John Diltz, of Ithaca, for many years a fisherman, and Mr. E. C. Stillwell, now of Ithaca but formerly a ferryman at Kidder's both state that the alewife was introduced about 1872. Mr. John Vann tells us that they were introduced purposely as food for the lake trout.

10. Family SALMONIDÆ. The Salmons and Trouts.

Coregonus clupeiformis (Mitchill). Common whitefish.

"I have seen no specimens of this species from the lake of which it is however undoubtedly an inhabitant" (Meek). Various reports have been received of whitefish taken from the lake but we have never seen one that was of this species. Mr. John Vann states that all of the so-called whitefish brought to his notice have proved to be ciscoes. We do not believe that it is found here, the fact that it has been introduced notwithstanding.

36. **Argyrosomus osmeriformis** (H. M. Smith). New York smelt

Still taken in fairly large numbers but not as common as formerly. Old fishermen tell us that it has never been abundant since the introduction of the alewife. Prior to that time, according to their statements, it was very abundant.

37. **Salmo fario** Linnæus. Brown trout (introduced).

This species of trout is found in considerable numbers in the lake inlet, Enfield, Sixmile and Taughannock creeks. During the last season a very large specimen was caught in the reservoir in Sixmile Creek.

38. **Salmo irideus** Gibbons. Rainbow trout (introduced).

Fairly common in the lake inlet and its tributaries. Mr. Vann has seen individuals make their way up over the low falls in Enfield Creek.

39. **Cristivomer namaycush** (Walbaum). Lake trout.

Common in the deeper portions of the lake. They have apparently increased in numbers within the past few years. Mr. Vann has observed that they follow the alewives into shallow water in the spring. During the late spring and summer months many individuals, dead from lamprey wounds, are picked up from the surface of the lake. Occasionally one is found not quite dead and with the lamprey still clinging.

40. **Salvelinus fontinalis** (Mitchill). Brook trout.

Common in suitable streams throughout the lake basin. During the summer of 1908 many of the younger individuals perished because of the long draught which dried many of the smaller streams.

IX. Order HAPLOMI.

11. Family UMBRIDÆ. The Mud Minnows.

41. **Umbra limi** (Kirtland). Mud minnow.

This species has never been taken at the south end of the lake. Meek took it in small numbers at Montezuma and Cayuga.

12. Family ESOCIDÆ. The Pikes.

42. **Esox reticulatus** (Le Sueur). Eastern pickerel.

Common throughout the basin. Many individuals from this region approach very closely the characteristics of *Esox vermiculatus*.

43. **Esox lucius** Linnæus. Northern pike.

Common throughout the basin.

13. Family PŒCILIIDÆ. The Killifishes.

44. **Fundulus diaphanus** (Le Sueur). Gray-back.

Abundant in the lake, marshes, flood lands and the lower courses of the streams.

X. Order HEMIBRANCHII.

14. Family GASTEROSTEIDÆ. The Sticklebacks.

45. **Eucalia inconstans** (Kirtland). Brook stickleback.

Common in standing water and pools both on the flats and uplands above falls.

XI. Order ACANTHOPTERI.

15. Family PERCOPSIDÆ. The Trout Perches.

46. **Percopsis guttatus** Agassiz. Trout Perch.

Common. Found in the south end of the lake and the lower courses of the streams. At the breeding season, which occurs during the first two weeks in May, they are abundant in the shallow sloughs of the marshes.

16. Family ATHERINIDÆ. The Silversides.

47. **Labidesthes sicculus** (Cope). Brook silverside.

"Not found near Ithaca. Several specimens taken from a small stream which empties into the canal a few rods south of Montezuma" (Meek). It is now found to be common at the south end of the lake over a muddy bottom along shore and in the lower courses of streams.

17. Family CENTRARCHIDÆ. The Sunfishes.

48. **Pomoxis sparoides** (Lacépède). Calico bass.

Common at the south end of the lake. During the late summer and early fall of 1906 the young of the species was abundant in the lower course of Fall Creek and its tributaries.

49. **Ambloplites rupestris** (Rafinesque). Rock bass.

Common. The young are abundant in the lower courses of all streams throughout the basin. It is not found above falls except in Eddy pond in Cascadilla Creek where its presence is probably to be explained in the same way as Notropis whipplii.

50. **Apomotis cyanellus** (Rafinesque). Green sunfish.

No specimens of this species have been recorded from the lake basin in recent years and never from the south end. Meek found a few near Montezuma.

51. **Lepomis pallidus** (Mitchill). Bluegill.

Meek found it in small numbers at Montezuma. None have been recorded from other localities in the basin.

52. **Eupomotis gibbosus** (Linnæus). Pumpkin seed.

Abundant throughout the basin. It spawns during the whole of June and first part of July.

53. **Micropterus dolomieu** Lacépède. Small-mouthed black bass.

Common. Meek recorded this species as not found by him at the south end of the lake where it is now common. During late summer and early fall the young are found abundantly in the lower courses of the streams tributary to the lake. By the last of August the young vary between four and five centimeters in length and by December have attained a length of from six to seven centimeters.

54. **Micropterus salmoides** (Lacépède). Large-mouthed black bass.
Common in the lake. Young of this species are found in summer and fall along with those of the former species. Specimens obtained in the streams in December average between seven and eight centimeters in length.

18. Family PERCIDÆ. The Perches.

55. **Stizostedion vitreum** (Mitchill). Wall-eyed pike.
Found in the lake but not common.

56. **Stizostedion canadense** (Smith) Sauger.
Found in the lake in about the same abundance as the preceding species.

57. **Perca flavescens** (Mitchill). Yellow perch.
Abundant throughout the basin. It spawns during the first of April.

58. **Percina caprodes zebra** (Agassiz). Manitou darter.
Rare. Two specimens have been recorded in this basin; one May 27, 1907, in Fall Creek near the mouth and one July 18, 1907, in the inlet about four miles from the lake.

59. **Boleosoma nigrum** (Rafinesque). Johnny darter.
One specimen taken in Renwick brook on the flats April 21, 1900, by T. L. Hankinson and C. O. Houghton.

60. **Boleosoma nigrum olmstedi** (Storer). Tessellated darter.
Common in the lake and tributaries below falls.

61. **Etheostoma flabellare** Rafinesque. Fan-tailed darter.
Common. Found in localities along with the preceding species.

19. Family SERRANIDÆ. The Sea Basses.

62. **Roccus chrysops** (Rafinesque). White bass.
Two specimens of this species have been taken from the lake basin; one from the inlet April 18, 1877, and one April 15, 1896.

20. Family COTTIDÆ. The Sculpins.

63. **Cottus ictalops** (Rafinesque). Blob.
Common at both ends of the lake in cold water. The eggs are

deposited in masses attached to the under side of stones where they are guarded by one of the parents.[15]

64. **Cottus gracilis** (Heckel). Miller's thumb.

Not common but found throughout the basin.

21. Family GADIDÆ. The Cods.

65. **Lota maculosa** (Le Sueur). Burbot.

Not common. Found only in deep water.

C. Class AMPHIBIA.

XII. Order PROTEIDA.

22. Family PROTEIDÆ. The Mud Puppies.

66. **Necturus maculosus** Rafinesque. Mud puppy.

Abundant in the lake and the lower courses of the inflowing streams. They have been taken in the inlet three miles from the lake.

XIII. Order URODELA.

23. Family AMBYSTOMIDÆ.

67. **Ambystoma punctatum** (Linnæus). Spotted salamander.

Common throughout the basin. Depending upon the season, egg-laying begins the last of March or the first of April immediately after emerging from hibernation. The earliest date March 13, 1903. Transformation of the larva begins the last of July or about four months after the eggs are laid. From this time to the middle of September transforming individuals may be found.

24. Family PLETHODONTIDÆ.

68. **Hemidactylium scutatum** Tschudi. Four-toed salamander.

Not common. The first specimens recorded were obtained near Ithaca in the valley of Sixmile Creek by H. W. Norris in April 1889. No other specimens were found in this basin until October 22, 1905, when twenty-one specimens were found on Larch Hill, two miles south of Ithaca on the east side of the inlet valley. They were all found under stones or about the bases of stumps in the open.

[15] Gage, S. H., "Notes on the Cayuga Lake Stargazer," *The Cornell Review*, November, 1876, p. 91.

69. **Plethodon erythronotus** (Green). Red-backed salamander, gray salamander.

Common. Found usually in dry places under stones or any object which will furnish cover. They appear from hibernation the last of March or the first of April. The earliest date upon which they have been recorded in the spring is March 17, 1903. The latest date on which they have been observed in the fall is November 1, 1903. The eggs are deposited during June and July, under logs, loose bark or in decaying wood, in bunches of from seven to twelve. Each egg is attached by a slender cord to a common focus and the whole cluster is attended by the female. The young transform immediately after hatching. There is every possible gradation between the red-backed and gray forms.[16] During the summer of 1908 a pure red individual was found at Chautauqua, N. Y.

70. **Plethodon glutinosus** (Green). Slimy salamander.

Common but limited to certain localities. Found usually in moist humus, manure piles, damp moss banks and decaying vegetation. Its breeding habits are not known.

71. **Gyrinophilus porphyriticus** (Green). Purple salamander.

Common. Found in all cold springs and streams flowing through gorges or ravines. They remain in the larval stage for a period of two years, at least. The only record of transformation which we have obtained is a specimen 11.5 cm. long found March 14, 1903, in which the larval characteristics have almost entirely disappeared. A female taken May 12, 1906, with mature eggs in the ovaries and what appeared to be a larva not long after hatching taken from a cold brook June 29, 1901, are the only clues we have to the breeding habits.

72. **Spelerpes bislineatus** (Green). Two-lined salamander.

Common in and about cold swift brooks. The breeding habits have not been observed in this locality.

[16] Reed, H. D., "A Note on the Coloration of *Plethodon cinereus*," *Am. Nat.*, Vol. 42, 1908.

25. Family DESMOGNATHIDÆ.

73. **Desmognathus fusca** (Rafinesque). Dusky salamander.

One of the most abundant salamanders in the lake basin. It is found under most any sort of object which will furnish cover in wet and marshy places along the cooler streams. The maximum period of egg-laying is July. The eggs are laid in clusters joined by a slight cord to a common focus but not attached to extraneous objects as in the case of *Plethodon erythronotus*. The female attends the eggs and is found usually with the body partly encircling them. The larvæ transform from September to December, when they are from 18 to 20 millimeters long.

26. Family PLEURODELIDÆ.

74. **Diemictylus viridescens** Rafinesque. Vermilion-spotted newt.

The most abundant salamander found in the lake basin. The adult is found in every pool, pond, ditch and stretch of standing water. Individuals in the red land stage are common on the woods under dead leaves and decaying bark and wood. The eggs are deposited singly upon the leaves of aquatic plants from April to June. Larvæ begin to transform to the red land stage in August, continuing until September. Some individuals pass the winter in the larval stage. After two and one half or three years the red land form assumes a viridescent coloration and becomes permanently aquatic.[17]

XIX. Order SALIENTIA.

27. Family BUFONIDÆ. The Toads.

75. **Bufo americanus** Le Conte. American toad.

Abundant. The average date of emergence from hibernation is April 15. The earliest recorded date is March 19, 1903. They proceed immediately to the water where the eggs are deposited. The maximum period of egg-laying is between April 20 and May 30, although stragglers continue to spawn until July. The larval period lasts for about sixty days, the tadpoles beginning to transform about the last of June. The latest fall record for this species is October 20, 1906.

[17] See Gage, S. H., "Life-history of the Vermilion-spotted Newt," *Am. Nat.*, 1891, p. 1084.

28. Family Hylidæ. The Tree Frogs.

76. **Hyla versicolor** Le Conte. Common tree toad.

Abundant. It appears from hibernation the last of April or very first of May. The eggs are laid the first of June in bunches of from four to twenty-five, which float at the surface either attached to vegetation or free. Transformation begins the first of August making the larval period of from fifty to sixty days duration. The latest fall record for this species is October 25, 1905.

77. **Hyla pickeringii** (Holbrook). Peeper.

Abundant. It emerges from hibernation the last of March. The height of the egg-laying season is April although individuals are found depositing their eggs as early as the last of March. The eggs are attached singly to vegetation beneath the surface of the water. Sometimes they are found in bunches of from four to twelve. Transformation begins the middle of July at the end of a larval period of from 90 to 100 days duration. The latest fall record is October 30, 1901.

29. Family Ranidæ. The Frogs.

78. **Rana pipiens** Schreber. Leopard frog.

The most abundant anuran throughout the basin. They come out from hibernation the last of March or the first of April. The eggs are seldom deposited before April 10 from which date active spawning continues for about four weeks. The tadpoles begin to transform the middle of July, about 100 days after the eggs are laid. The latest fall record is November 18, 1906.

79. **Rana palustris** Le Conte. Pickerel frog.

Common. The average date of its appearance in the spring is April 13. In some seasons it has been found to emerge the last of March. The eggs are deposited in bunches attached to submerged twigs and grasses. As a rule egg-laying does not begin until the last of April. They may be distinguished from the eggs of other frogs of this region by their decided yellow color. The tadpoles transform the last of July, about 90 days after the eggs are deposited. The latest fall record for the species is November 1, 1902.

80. **Rana clamata** Daudin. Green frog.

Common. It appears from hibernation the middle of April. The eggs are not laid until the first of June, through this month, July and a part of August. The eggs are deposited in a frothy film which floats at the surface of the water. The larval period is of about thirteen months duration transformation beginning the middle of the July of the following year in which the eggs are laid. The latest fall record is November 1, 1902.

81. **Rana catesbeiana** Shaw. Bull frog.

Common. This is the last one of the frogs to emerge from hibernation, never appearing before the middle of May. The eggs are laid the last of June and the first of July in an irregular sheet or film attached to sticks or twigs near the surface of the water. The larval stage lasts for a period of two years, the tadpoles transforming in July and August of the second year following hatching.

82. **Rana sylvatica** Le Conte. Wood frog.

Common. It appears in the spring, the last of March or the first of April. Egg-laying begins almost immediately. The young transform the last of June about 90 days after the eggs are laid. The latest fall record is November 1, 1906.

D. Class REPTILIA.

XX. Order OPHIDIA.

30. Family Colubridæ. The Harmless Snakes.

83. **Diadophis punctatus** (Linnæus). Ring-necked snake.

Common. The earliest date upon which it has been observed in the spring is April 19, 1900. The latest fall date is October 16, 1905.

84. **Liopeltis vernalis** (Harlan). Smooth green snake.

Not common. De Kay, however, records it as common at the north end of the lake in the marshes. The latest fall record is October 20, 1906.

85. **Bascanion constrictor** (Linnaeus). Black snake.

Formerly common. Now confined to the region about Newfield and Danby in the southern portion of the basin.

86. **Coluber obsoletus obsoletus** Say. Racer.

Rare. Only four specimens recorded for the basin. Two of these were taken June 14, 1883, one during the summer of 1889 and the fourth, a specimen five feet long, was captured alive at Newfield in August, 1899.

87. **Lampropeltis doliatus triangulus** (Boie). Milk snake.

Common throughout the basin.

88. **Lampropeltis doliatus collaris** (Cope).

One specimen taken June 16, 1903. So far as we know this is the first record of this variety for the state. The specimen agrees with Cope's figure and description and with a specimen of *collaris* taken at Danville, Ill.

89. **Natrix sipedon** (Linnæus). Water snake.

Abundant throughout the basin, especially in the marshes where on clear days they are found coiled on stools of dead sedges.

90. **Storeria occipitomaculata** (Storer). Red-bellied snake.

Common throughout the basin under logs, pieces of bark and dead leaves along hillsides and dry places. In the fall they are seen in the open upon lawns, roads and walks. The earliest spring record is March 18, 1903. The latest fall record is October 21, 1906.

91. **Thamnophis saurita** (Linnæus). Ribbon snake.

Common, especially in the lowlands and moist meadows. The earliest spring record is March 19, 1905. The latest they have been seen in the fall is October 30, 1901.

92. **Thamnophis sirtalis sirtalis** (Linnæus). Striped garter snake.

This is the most abundant snake in the basin. They appear in the spring about the first of April and are abroad until the last of October.

31. Family CROTALIDÆ. The Pit Vipers.

93. **Crotalus horridus** Linnæus. Common rattlesnake.

Formerly abundant. They are still met with about McLean.

XXI. Order LACERTILIA.

32. Family Scincidæ. The Skinks.

94. **Leiolopisma laterale** (Say). Ground lizard.

One specimen (No. 3550) taken at Caroline April 23, 1892, by W. J. Terry and L. A. Fuertes.

XXII. Order TESTUDINATA.

33. Family Trionychidæ. The Soft-shelled Turtles.

95. **Aspidonectes spinifer** (Le Sueur). Common soft-shelled turtle.

Common at the north end of the lake. A few specimens have been taken at the south end.

34. Family Chelydridæ. The Snapping Turtles.

96. **Chelydra serpentina** (Linnæus). Snapping turtle.

Common. Found in all marshy places. The earliest spring record is April 13, 1906. The eggs hatch the first of October. On October 3, 1883, twenty-four specimens were found that had just hatched. A few were still in the nest but the larger number were in line moving towards water.

35. Family Kinosternidæ. The Musk Turtles.

97. **Terrapene odorata** (Latreille). Musk turtle.

Common in the Seneca river and marshes about Montezuma where it was first found by A. A. Allen and J. T. Lloyd, September 24, 1908.

36. Family Emydidæ. The Pond Turtles.

98. **Chrysemys marginata** (Agassiz). Agassiz' painted turtle.

Abundant throughout the basin. On January 25, 1906, a single individual was observed swimming under the ice on a pond near Ithaca. The same day 150 were taken by fishermen at the head of the lake. This early emergence from hibernation was due to the extremely mild winter up to that date and the unusually warm week of January 25. On the same date this species was observed along the southern shore of Lake Ontario.

99. **Clemmys muhlenbergii** (Schoepff). Muhlenberg's tortoise.

For the present this species must be considered rare. Thus far only three specimens have been taken; one on June 15, 1877, near Ithaca, and two at Junius, May 26, 1906. The specimen taken near Ithaca was kept alive for a time and on July 20 deposited eggs in the sand of the terrarium.

100. **Clemmys insculpta** (Le Conte). Wood tortoise.

Common throughout the basin in wooded regions along water courses.

101. **Clemmys guttata** (Schneider). Spotted turtle.

The only records of this species are from Junius in the extreme northwestern portion of the basin where it is common.

E. Class AVES.

XXIII. Order PYGOPODES. The Diving Birds.

37. Family Colymbidæ. The Grebes.

102 (2).[18] **Colymbus holboelli** (Reinhardt). Holboell's grebe.

Not an uncommon transient during April and November. A few are found regularly in winter. The latest spring record for this species in the basin is May 25, 1907. They are seldom taken at the south end of the lake.

103 (3). **Colymbus auritus** Linnæus. Horned grebe.

Common transient from April 1 to May 10 and occasionally taken in winter. In the spring they become common about the middle of April and all have disappeared by May 10. They appear in the fall the first of October, gradually increasing in numbers until November throughout which they are common.

104 (6). **Tachybaptus podiceps** (Linnæus). Pied-billed grebe.

A common transient and an uncommon but regular summer resident in the marshes at the north end of the lake. In the spring they appear April 1 and are common throughout the month. In the fall they become common the first of October and continue so until November 1. The latest fall record is a young female taken Novem-

[18] The number of the species in "Check-list of the American Ornithologists' Union."

ber 15, 1897. In a collection of birds made at Ithaca about fifty years ago are several immature specimens ranging in size from just hatched to birds two-thirds grown. In the spring of 1909 a nest was found in the Renwick marshes.

38. Family GAVIIDÆ. The Loons.

105 (7). **Gavia immer** (Brünnich). Common loon.

Common transient. They appear in the spring from April 14 to May 20, being the most common the very last of April. On April 28, 1908, Mr. L. A. Fuertes reported a flock of 50 off the mouth of Taughannock Creek. All of our fall records of this species occur between October 29 and November 29. Audubon mentions this species as breeding on Cayuga Lake in 1824.

106 (11). **Gavia stellata** (Pontoppidan). Red-throated loon.

Rare. There is a specimen of a male in the collection of Cornell University taken on Cayuga Lake at Ithaca, November 4, 1875, by Dr. M. J. Roberts. Another specimen was taken at Sheldrake a few years ago by Jacob Cram. It was identified by L. A. Fuertes, who states that it was probably killed in November, 1889.

39. Family ALCIDÆ. The Auks.

107 (31). **Uria lomvia** (Linnæus). Brünnich's murre.

Occasionally seen in recent years. The first record for Cayuga Lake was a specimen reported in 1854 by William Hopkins of Auburn.[19] On December 14, 1895, a specimen was shot and is now in the possession of H. G. Wilson, of Ithaca. On December 16 of the same year two more specimens were killed. According to our records they did not appear again until the fall of 1899 when in November a female was obtained. Eaton[20] mentions them as on "Cayuga Lake, winter of 1899." The next record was a specimen taken at Ithaca December 19, 1901 by T. L. Hankinson. Since that date we have no knowledge of this species on the lake.

[19] Hopkins, William, *Proc. Boston Soc. Nat. Hist.*, Vol. V., p. 13, July, 1854.

[20] Eaton, E. H., "Birds of Western New York," *Proc. Rochester Acad. Sci.*, Vol. IV., pp. 1–164.

XXIV. Order LONGIPENNES. The Long-winged Swimmers.

40. Family Laridæ. The Gulls and Terns.

108 (40). **Rissa tridactyla** (Linnæus). Kittiwake.

A specimen was reported by William Hopkins in 1854.

109 (43). **Larus leucopterus** Faber. Iceland gull.

A specimen was taken on Cayuga Lake by L. A. Fuertes during the winter of 1896–7 and another was brought in by a fisherman March 17, 1897.

110 (51). **Larus argentatus** Pontoppidan. Herring gull.

Common winter resident. It is abundant during the spring and fall. They appear in the fall the first of September and leave in the spring about May 25 the latest record being June 2, 1906.

111 (54). **Larus delawarensis** Ord. Ring-billed gull.

Foster Parker, of Cayuga, has a specimen taken on the lake a few years ago.

112 (60). **Larus philadelphia** (Ord). Bonaparte's gull.

Transient. Common in spring, rare in fall. It is found in the spring from April 20 to May 25 and is usually common during that period. On June 14, 1908, a flock of eleven individuals was reported at the south end of the lake and on July 24 of the same year L. A. Fuertes reported a single individual from Cayuga at the north end of the lake. In the fall this species is found occasionally in October and November.

113 (62). **Xema sabinei** (Sabine). Fork-tailed gull.

One specimen taken at the north end of the lake about 1887 by Foster Parker. It is now in the collection of E. H. Eaton.

114 (70). **Sterna hirundo** Linnæus. Common tern.

Regular, though not common, transient through May and the first of June. Mr. L. A. Fuertes reports a specimen the latter part of April 1898 and two adults near the mouth of Fall Creek at Ithaca, July 6, 1908. The only fall record of this species is a single individual reported by L. A. Fuertes the last of August, 1907.

115 (74). **Sterna antillarum** (Lesson). Least tern.

Mr. F. R. Rathbun[21] recorded two specimens taken on Cayuga Lake.

116 (77). **Hydrochelidon nigra surinamensis** (Gmelin). Black tern.

Not an uncommon spring migrant during the last half of April and the first of May. Foster Parker has found them nesting on old musk rat houses in the Cayuga marshes. L. A. Fuertes took a specimen August 28, 1900, at Ithaca, and reported three others seen at the same time.

XXV. Order TUBINARES. The Tube-nosed Swimmers.

41. Family PROCELLARIIDÆ. Shearwaters and Petrels.

117 (98). **Æstrelata hasitata** (Kuhl). Black-capped petrel.

There was a specimen in the collection of L. S. Foster, number 759, taken in Cayuga Co., early in September, 1893.

XXVI. Order STEGANOPODES. The Totipalmate Birds.

42. Family PHALACROCORACIDÆ. The Cormorants.

118 (119). **Phalacrocorax carbo** (Linnæus). Common cormorant.

A specimen was reported by William Hopkins as taken by him at Auburn.

119 (120). **Phalacrocorax auritus** (Lesson). Double-crested cormorant.

Rare. An adult male was taken November 16, 1875, by Dr. J. M. Roberts. A second specimen was taken September 29, 1905, at Aurora, N. Y., and is now in the collection of Wells College. An immature specimen was obtained at Ithaca, August 2, 1906, by L. A. Fuertes.

43. Family PELECANIDÆ. The Pelicans.

120 (125). **Pelecanus erythrorhynchos** Gmelin. White pelican.

There are two records of this species for Cayuga Lake. A specimen was obtained by Mr. Cave in 1876, concerning which Mr. J. W. Beal[22] writes as follows:

[21] Rathbun, Frank R., "A Revised List of the Birds of Central New York," p. 41, Auburn, N. Y.

[22] Beal, J. W., *American Naturalist*, Vol. I. (1867), p. 323.

Sometime during the spring of 1864, near a marsh on Cayuga Lake, two large birds were seen for several weeks, but one of them left a few days before the other was killed. None of the hunters had ever seen anything of the kind about here before. It proved to be a specimen of the white or rough-billed pelican (*Pelecanus erythrorhynchus* Gmelin), in good condition, and its wings measured fully eight feet from tip to tip.

In the late summer about 1888 Foster Parker killed a specimen which is now in the New York State Museum.

XXVII. Order ANSERES. Lamellirostral Swimmers.

44. Family ANATIDÆ. The Ducks and Geese.

121 (129). **Mergus americanus** Cassin. Merganser.

Common winter resident from the middle of October to the last of April. The latest spring record is April 27, 1907, upon which date they were still common.

122 (130). **Mergus serrator** Linnæus. Red-breasted merganser.

Common transient and found in small numbers during the winter. It is not common after April 25 and the latest date upon which they have been recorded in the spring is May 25, 1907.

123 (131). **Lophodytes cucullatus** (Linnæus). Hooded merganser.

Common transient from the last of March to the last of April. Foster Parker reports it as breeding occasionally in the Montezuma marshes. In the fall individuals are common from the middle of October to the middle of November.

124 (132). **Anas platyrhynchos** Linnæus. Mallard.

Common transient during March and April and again in October. It is sometimes found in winter and Foster Parker reports it as breeding in the marshes at the north end of the lake. They first appear in the fall about the middle of September and remain as late as the last of November but are most common in October.

125 (133). **Anas rubripes tristis** Brewster. Black duck.

Common transient and regular but not common in winter. It breeds regularly and in fair numbers in the Canoga and Montezuma marshes.

126 (135). **Chaulelasmus streperus** (Linnæus). Gadwall.

Common transient the latter part of March and the entire month of April. They appear in the fall the last of September and remain until the very last of October. The latest fall record is a male killed November 20 at Cayuga. This species is not common at the south end of the lake.

127 (136). **Mareca penelope** (Linnæus). European Widgeon.

Mr. F. S. Wright of Auburn has a specimen killed on Cayuga lake in the spring of 1881. It is an adult male in full plumage. Foster Parker reports that several have been killed at Cayuga.

128 (137). **Mareca americana** (Gmelin). Baldpate.

Common transient from March 23 to April 26, the bounding dates of our records. In the fall they appear during the last week of September and remain until the first of November. The latest date upon which they have been recorded in any numbers is October 22, 1905.

129 (138). **Nettion crecca** (Linnæus). European teal.

Accidental. A male was shot by Will Canfield at Cayuga, April 10, 1902. The specimen was identified by E. H. Eaton.

130 (139). **Nettion carolinensis** (Gmelin). Green-winged teal.

Common transient during April and October. Arrivals are to be noted the last of September but it is most common during October. This species is very rarely found in winter.

131 (140). **Querquedula discors** (Linnæus). Blue-winged teal.

Common transient during April and in the fall during the last half of September and throughout October. It formerly bred in fairly large numbers in the marshes at the north end of the lake.

132 (142). **Spatula clypeata** (Linnæus). Shoveller.

Common transient. It is not often found at the south end of the lake.

133 (143). **Dafila acuta** (Linnæus). Pintail.

Transient during the last of March and the first of April and in the fall during October and the first half of November.

134 (144). **Aix sponsa** (Linnæus). Wood duck.

Summer resident but not as common as formerly. It still breeds in small numbers at Cayuga. During the summer of 1907 a pair nested in the woods of the Renwick marshes at Ithaca.

135 (146). **Marila americana** (Eyton). Red head.

Common transient and regularly present in winter. In the spring it is common from the middle of March throughout April. In the fall it is found during October and November.

136 (147). **Marila vallisneria** (Wilson). Canvas-back.

Common transient and a regular winter visitant in smaller numbers from the middle of November to the last of March.

137 (148). **Marila marila** (Linnæus). American scaup duck.

Winter resident from the first of October to the very last of April. It is more common during migration.

138 (149). **Marila affinis** (Eyton). Lesser scaup duck.

Common transient. A few are occasionally found in winter. They arrive in the fall the first of October and remain until the middle of November. In the spring they are to be found from April 1 to June 24, the latest date.

139 (150). **Marila collaris** (Donovon). Ring-necked duck.

Usually a rare transient. Foster Parker reports it as common during the spring of 1905 at the north end of the lake.

140 (151). **Clangula clangula americana** (Bonaparte). Golden-eye.

Common winter resident from November 1 to April 1.

141 (152). **Clangula islandica** (Gmelin). Barrow's golden-eye.

Rare. One specimen, an adult female, taken at Cayuga by L. A. Fuertes, December 20, 1906. (Coll. of L. A. F., no. 1523.)

142 (153). **Charitonetta albeola** (Linnæus). Buffle-head.

Common transient. It appears in the spring from the middle of April to the last of May. In the fall arrivals from the north appear usually the second week in October and remain until the last of November.

143 (154). **Harelda hyemalis** (Linnæus). Old-squaw.

Common transient and not uncommon in winter. They arrive the middle of October and remain until the first of May.

144 (162). **Somateria spectabilis** (Linnæus). King eider.

"A mounted specimen of an adult male, taken on Cayuga lake, is now in the barroom of the Cornell House at Trumansburg, N. Y." (L. A. Fuertes). On November 3, 1908, at Cayuga four individuals, three females and an immature, were shot from a flock of twenty.

145 (163). **Oidemia americana** Swainson. Scoter.

Common transient and uncommon winter resident. The earliest fall record is a specimen shot October 13, 1885.

146 (165). **Oidemia deglandi** Bonaparte. White-winged scoter.

Common winter resident from October 3 to May 1.

147 (166). **Oidemia perspicillata** (Linnæus). Surf scoter.

Uncommon. We have no spring records of this species. The earliest date upon which it has been recorded in the fall is that of a specimen shot by L. A. Fuertes, October 13, 1906.

148 (167). **Erismatura jamaicensis** (Gmelin). Ruddy duck.

Common transient in the fall from October 1 to November 1. It is occasionally taken in the spring but much less common at this season.

149 (169*a*). **Chen hyperborea nivalis** (Forster). Greater snow goose.

Two young were killed near Ithaca during the last of March, 1876.[23]

150 (169.1). **Chen cærulescens** (Linnæus). Blue goose.

Two specimens, male and female, were killed a few years ago on Cayuga Lake by Foster Parker. They are now in the New York State Museum.

151 (172). **Branta canadensis** (Linnæus). Canada goose.

Common transient and an occasional winter resident. They are common in the spring from March 10 to May 7. In the fall this species begins to arrive from the north about October 1 and is present until December 1. The latest record of what appeared to be migrating flocks is December 9, 1907.

[23] *Forest and Stream,* Vol. 7, p. 283.

152 (173*a*). **Branta bernicla glaucogastra** (Brehm). Brant.

Rare. No specimens of this species have been recorded from the lake basin in recent years. Foster Parker has in his possession a specimen shot on Cayuga Lake a few years ago. From the Auburn List[24] we quote the following:

> One shot on Cayuga Lake, N. Y., near the railroad bridge by Mr. Charlie Traverse. The same was identified by Mr. Greene Smith.—Horace Silsby, in *Auburn Daily Bulletin* of December, 1877. An adult male received from Cayuga Lake, November 26, 1878, which was also shot near the railroad bridge by Mr. David Copeman.

153 (180). **Olor columbianus** (Ord). Whistling swan.

Rare. Two specimens were shot by Foster Parker a few years ago and another is recorded by Fowler, Wright and Rathbun[25] from the Seneca River. On March 16, 1908, a flock of 118 individuals was reported from the north end of the lake. According to Father Raffeix swan were common on the lake in the days of the Jesuits for he writes:[26] "It [Cayuga] abounds in swan and geese all winter."

XXVIII. Order HERODIONES. The Heron-like Birds.

45. Family Ibididæ. The Ibises.

154 (186). **Plegadis autumnalis** (Hasselquist). Glossy ibis.

William Hopkins recorded a specimen from Cayuga Lake in 1854. There are two specimens in the possession of Foster Parker taken on the Seneca River in 1902. F. S. Wright shot one specimen and saw three others on Howland Island in May, 1902. On May 27, 1907, two males and two females were shot at Cayuga by Foster Parker.

46. Family Ardeidæ. The Herons.

155 (190). **Botaurus lentiginosus** (Montagu). Bittern.

Common summer resident. It nests in every marsh of any size throughout the basin. The average date of spring arrival is April 15, the earliest, March 28, 1908. Nesting begins the middle of May

[24] "A Revised List of Birds of Central New York," collected and prepared for publication by Frank R. Rathbun, Auburn, N. Y.

[25] *Ornithologist and Oölogist*, Vol. 7, p. 133.

[26] Father Raffeix, "Relations for the Year 1671–72," Quebec edition, p. 22.

and continues for the rest of the month. Young in the nest are found from the first to the middle of June. They depart for the south the first of November.

156 (191). **Ixobrychus exilis** (Gmelin). Least bittern.

Common summer resident. The average date of spring arrival is May 15, the earliest May 9, 1908. The active period of nesting extends from May 20 to June 10. Young are found in the nest from about June 8 to June 25. We have no records of this species in the fall later than September 10.

157 (194). **Ardea herodias** Linnæus. Great blue heron.

Common spring and fall transient and summer resident at Meridian, N. Y., at the north end of the basin. The average date of spring arrival is March 28, the earliest, March 18, 1890. In the fall they appear at the south end of the basin the last of July, the earliest record being a specimen taken July 18, 1889, by L. A. Fuertes. We have no records indicating that this species remains after November 1.

158 (196). **Herodias egretta** (Gmelin). Egret.

This species was recorded in 1854 by William Hopkins. Foster Parker has in his collection a specimen shot at Cayuga but without record or recollection of date.

159 (201). **Butorides virescens** (Linnæus). Green heron.

Common summer resident. The average date of spring arrival is May 2, the earliest, April 18, 1906. Nesting begins about May 10 and continues until the middle of July. On July 11, 1906, four nests were found, one containing four eggs and the others, young birds which left the nest upon approach. This species leaves in the fall about the last of September, the latest record being October 2, 1902.

160 (202). **Nycticorax nycticorax nævius** (Boddaert). Black-crowned night heron.

Never common but a regular spring and fall migrant. In the former season our records extend from May 11 to June 2, in the latter from July 14 to October 29.

XXIX. Order PALUDICOLÆ. The Cranes and Rails.

47. Family Gruidæ. The Cranes.

161 (204). **Grus americana** (Linnæus). Whooping crane.

"Several years ago a specimen was killed on Cayuga Lake—Frank A. Ward" (Eaton, 1901).

48. Family Rallidæ. The Rails.

162 (208). **Rallus elegans** Audubon. King rail.

Not an uncommon summer resident in the marshes at the north end of the basin. There is but one record of this species at the south end of the lake, an adult male shot November 29, 1901.

163 (212). **Rallus virginianus** Linnæus. Virginia rail.

Common summer resident in all the marshes throughout the basin. The average date of spring arrival is May 1, the earliest, April 24, 1904. They nest the last half of May and throughout June. The earliest date for nest is May 18, 1905. The latest date upon which nest and eggs have been found is July 9, 1906. They are abundant throughout September and the first half of October. All have usually departed by November 1.

164 (214). **Porzana carolina** (Linnæus). Sora.

Common summer resident throughout the basin. The average date of spring arrival is May 1, the earliest, April 14, 1908. About the middle of October this species becomes exceedingly abundant and usually all have left by the last of the month. The nesting period is the same as for the preceding species.

165 (215). **Coturnicops noveboracensis** (Gmelin). Yellow rail.

Mr. F. S. Wright, of Auburn, reports that two or three have been taken at the north end of the lake. One of them was a male shot at Meridian, N. Y., in 1897.

166 (219). **Gallinula galeata** (Lichtenstein). Florida gallinule.

Fairly common summer resident in the marshes at the north end of the lake where it arrives the last of April. Ralph and Bagg[27]

[27] Ralph, William L., and Bagg, Egbert, "Annotated List of the Birds of Oneida County, N. Y., and Its Immediate Vicinity," *Trans. of the Oneida Historical Society,* Vol. III., p. 101, 1886.

recorded this species as very common in the marshes of Seneca River where they bred in great numbers. In recent years it has not been recorded near Ithaca. E. H. Eaton informs us that C. J. Pennock saw a female with young in the Renwick marshes in July, 1879. Cornell University has recently come into the possession of a collection of birds made near Ithaca in 1850. Among the skins is one of an adult male and one of a young individual in first plumage.

167 (221). **Fulica americana** Gmelin. Coot.

Common transient the last of April and the first of May and an occasional summer resident in the marshes at both ends of the lake. On May 25, 1907, a nest containing five eggs was found in the west marsh at Ithaca. On June 1 it contained ten eggs and on June 9, when it was last visited, the number was the same. During October this species is very common and departs usually by the last of the month.

XXX. Order LIMICOLÆ. The Shore Birds.

49. Family Phalaropodidæ. The Phalaropes.

168 (222). **Phalaropus fulicarius** (Linnæus). Red phalarope.

Rare transient visitant. William Hopkins reported a specimen in 1854. In the collection of Cornell University there is a specimen of a male killed on Cayuga Lake October 18, 1885, by E. H. Sargent.

169 (223). **Lobipes lobatus** (Linnæus). Northern phalarope.

In the collection of E. H. Eaton are two specimens, male and female, taken at Montezuma in 1895. In the collection of Cornell University is a specimen taken at Ithaca in 1850.

170 (224). **Steganopus tricolor** (Vieillot). Wilson's phalarope.

One specimen, a young individual, was obtained by L. A. Fuertes at Ithaca in the fall of 1892.

49*a*. Family Recurvirostridæ. The Avocets and Stilts.

170*a* (225). **Recurvirostra americana** Gmelin. Avocet.

One specimen (C. U. 5219) was taken at Renwick, September 16, 1909, by Mr. A. A. Allen.

50. Family SCOLOPACIDÆ. The Snipe.

171 (228). **Philohela minor** (Gmelin). Woodcock.

Summer resident in moist areas throughout the basin. They arrive in the spring the last of March and leave in the fall during the first two weeks of November. The woodcock is slowly increasing in numbers about Ithaca. Mr. John Vann tells us that in the fall of 1908 all the individuals of several localities succeeded in migrating without any loss from shooting. He attributes the increase partly to the growth of cover in the uplands where they are found during the fall.

172 (230). **Gallinago delicata** (Ord). Wilson's snipe.

Common transient between April 12 and May 20. In 1908 one was recorded on April 3. They are most abundant during the latter part of April. Our autumn records fall between September 22 and November 18. The downy young were found at Meridian, N. Y., by E. G. Taber and F. S. Wright states that it is a rare breeder in the marshes at Cayuga.

173 (231). **Macrorhamphus griseus** (Gmelin). Dowitcher.

There is a specimen in the collection of Foster Parker taken on Cayuga lake but without other data. From August 18 to 26, 1908 Foster Parker shot one and saw five others.

174 (233). **Micropalama himantopus** (Bonaparte). Stilt sandpiper.

Foster Parker shot a specimen at Cayuga October 10, 1907, in a flock of red-backed sandpipers. August 25, 1908, E. H. Eaton took a specimen at Cayuga and two more on September 20. On September 28, 1908, A. A. Allen and J. T. Lloyd shot a specimen at the north end of the lake.

175 (234). **Tringa canutus** Linnæus. Knot.

Two specimens were shot at Cayuga by Foster Porker, August 30, 1908. Mr. E. H. Eaton and Mr. L. A. Fuertes report them as frequently seen at Cayuga in the fall. It is altogether probable that this species is not an uncommon transient.

176 (239). **Pisobia maculata** (Vieillot). Pectoral sandpiper.

Common transient at the north end of the lake but rare at the south end. L. A. Fuertes has taken one specimen at Ithaca on each

of the following dates: During the fall of 1892, August 13, 1899, and October 12, 1890.

177 (240). **Pisobia fuscicollis** (Vieillot). White-rumped sandpiper.

One specimen taken at Montezuma October 12, 1906, by L. A. Fuertes.

178 (242). **Pisobia minutilla** (Vieillot). Least sandpiper.

Common transient. Most common in spring from May 7 to 27. The latest fall record is October 12, 1906. Regarding the time of first appearance in the fall we have no data.

179 (243*a*). **Pelidna alpina sakhalina** (Vieillot). Red-backed sandpiper.

Common transient being most abundant in the fall during October.

180 (246). **Ereunetes pusillus** (Linnæus). Semipalmated sandpiper

Common transient. In the spring they are found all through May. In the fall they appear August 20 and leave November 1. They are most common during the first half of October.

181 (248). **Calidris leucophæa** (Pallas). Sanderling.

Specimens are frequently taken at both ends of the lake. It appears to be a fairly common transient in both spring and fall.

182 (251). **Limosa hæmastica** (Linnæus). Hudsonian godwit.

"A rare spring and autumn migrant" (Auburn List). A specimen was taken at Ithaca about November 5, 1878, by C. J. Pennock and mounted by R. B. Hough.

183 (254). **Totanus melanoleucus** (Gmelin). Greater yellow-legs.

Transient. Fairly common from April 30 to May 20. It is common in the fall during October.

184 (255). **Totanus flavipes** (Gmelin). Yellow-legs.

Common transient from May 10 to June 1, the earliest spring date being April 28, 1908. It is common in the fall during October. The latest fall date is November 10, 1900.

185 (256). **Helodromas solitarius** (Wilson). Solitary sandpiper.

Common transient from April 28 to May 20 and July 14 to Sep-

tember 20. The average date of spring arrival is May 1, the earliest date being April 28, 1905.

186 (258). **Catoptrophorus semipalmatus** (Gmelin). Willet.

"A regular migrant. Three secured in the fall of 1876" (Auburn List, p. 33). This species has not been recorded in recent years.

187 (261). **Bartramia longicauda** (Bechstein). Upland plover.

The only record of this species which we have is a pair found breeding by Foster Parker during the summer of 1907. In the Auburn List (p. 33) it is spoken of as not an uncommon summer resident.

188 (263). **Actitis macularia** (Linnæus). Spotted sandpiper.

Common summer resident. The average date of spring arrival is April 24, the earliest, April 20, 1906. The active nesting period is from May 20 to June 15. L. A. Fuertes reports that he has found nests with eggs as late as July 26 (1900).

189 (264). **Numenius americanus** Bechstein. Long-billed curlew.

"A regular but somewhat rare migrant" ("Auburn List," p. 23). Not recorded in recent years.

190 (265). **Numenius hudsonicus** Latham. Hudsonian curlew.

"Occurs irregularly during the migration. One specimen preserved in the collection of the Phœnix Sportsman's Club at Seneca Falls, N. Y. ("Auburn List," p. 34). There is a specimen (C. U. 1158), in the collection of Cornell University taken at Union Springs in 1882.

51. Family CHARADRIIDÆ. The Plovers.

191 (270). **Squatarola squatarola** (Linnæus). Black-bellied plover.

Regular transient in the fall and occasionally in spring. On October 14, 1899, L. A. Fuertes shot a specimen at Ithaca which constitutes the only record for the south end of the basin. Mr. A. A. Allen and Mr. J. T. Lloyd reported it common at the north end of the lake on September 26, 1908. Our fall records all occur between September 20 and October 30.

192 (272). **Charadrius dominicus** Müller. Golden plover.

The only record of this species is a specimen taken by E. H. Eaton and L. A. Fuertes at Cayuga, October 29, 1907.

193 (273). **Oxyechus vociferus** (Linnæus). Killdeer.

Common transient and not uncommon summer resident from March 12 to November 15. It is most abundant in the fall.

194 (274). **Ægialitis semipalmata** Bonaparte. Semipalmated plover.

Transient. Uncommon in the spring, fairly common in the fall from August 15 to September 30.

52. Family APHRIZIDÆ. The Turnstones.

195 (283*a*). **Arenaria interpres morinella** (Linnæus). Turnstone.

Mr. L. A. Fuertes took a specimen at Ithaca June 3, 1906 and Foster Parker reports several taken at Cayuga.

XXXI. Order GALLINÆ. The Gallinaceous Birds.

52*a*. Family ODONTOPHORIDÆ. The Quail.

196 (289). **Colinus virginianus** (Linnæus). Bob-white.

Common permanent resident. It is very scarce all along the eastern part of the basin.

53. Family TETRAONIDÆ. The Grouse.

197 (300). **Bonasa umbellus** (Linnæus). Ruffed grouse.

Common permanent resident. All of our nesting records fall between April 20 and May 15.

XXXII. Order COLUMBÆ. The Doves.

54. Family COLUMBIDÆ. The Pigeons.

198 (315). **Ectopistes migratorius** (Linnæus). Wild pigeon.

Formerly abundant. None have been recorded here since 1892 when "A few were seen in Ithaca—L. A. F." (Eaton, p. 32).

199 (316). **Zenaidura macroura carolinensis** (Linnæus). Mourning dove.

Common summer resident. The average date of spring arrival is April 1, the earliest, March 8, 1890. Nest building has been found to begin as early as April 15 and eggs have been found until June

18. In the Renwick marshes they nest in colonies varying from three or four to a dozen pairs. The nests are frequently only a few feet apart, built upon stumps, brush piles, logs and heaps of debris.

XXXIII. Order RAPTORES. The Birds of Prey.

55. Family CATHARTIDÆ. The American vultures.

200 (325). **Cathartes aura septentrionalis** (Wied). Turkey vulture.

Mr. C. J. Hampton saw eight individuals hovering above a rank woodchuck on July 1, 1900, at Cosad, N. Y. One specimen was shot. On June 20, 1908, Mr. J. T. Lloyd reported one from the Renwick flats at Ithaca.

56. Family BUTEONIDÆ. The Hawks and Eagles.

201 (331). **Circus hudsonius** (Linnæus). Marsh hawk.

Common summer resident. The average date of spring arrival is March 27, the earliest being March 25, 1906. They remain in Autumn until the last of October, the latest fall record being October 28, 1908. The only nesting records of this species which we have are: a nest and eggs found May 27, 1904, and a nest with five young found June 29, 1906.

202 (332). **Accipiter velox** (Wilson). Sharp-shinned hawk.

Common summer resident and occasionally taken in winter. It is common from the last of March until the first of November. The only breeding record is a nest of young which took wing on July 16, 1906.

203 (333). **Accipiter cooperi** (Bonaparte). Cooper's hawk.

Common summer resident, more abundant in the fall. The average date of spring arrival is March 25, the earliest, March 17, 1907. They remain in the fall until November 1.

204 (334). **Astur atricapillus** (Wilson). Goshawk.

Uncommon winter visitant. A specimen was taken near West Candor, November 26, 1907, by C. S. Gridley. Mr. Fuertes reports that he sees one or more every winter. It is recorded in the Auburn List as an "uncommon winter visitor."

205 (337). **Buteo borealis** (Gmelin). Red-tailed hawk.
Common resident species.

206 (339). **Buteo lineatus** (Gmelin). Red-shouldered hawk.
Common resident species and more common in winter than the preceding species. The earliest nesting date recorded is April 26, 1905.

207 (343). **Buteo platypterus** (Vieillot). Broad-winged hawk.
Uncommon summer resident. The earliest spring record, March 16, 1906.

208 (347*a*). **Archibuteo lagopus sancti-johannis** (Gmelin). Rough-legged hawk.
Regular but not common winter visitant from Jan. 1 to April 1.

209 (352). **Haliaetus leucocephalus** (Linnæus). Bald eagle.
Not common permanent resident. It is more frequently seen in the spring and fall. It bred formerly near Crowbar point and still breeds in the vicinity of Union Springs.

56*a*. Family Falconidæ. The Falcons.

210 (356). **Falco peregrinus anatum** (Bonaparte). Duck hawk.
Rare transient during spring and fall.

211 (357). **Falco columbarius** Linnæus. Pigeon hawk.
Uncommon transient.

212 (360). **Falco sparverius** Linnæus. Sparrow hawk.
Common summer resident from March 15 to November 15 and occasionally taken in winter.

56*b*. Family Pandionidæ. The Fish Hawks.

213 (364). **Pandion haliaëtus carolinensis** (Gmelin). Osprey.
Common transient during May and October. Several are seen every year during the summer months but we have no evidence that they nest within the basin. The average date of spring arrival is April 12, the earliest, April 5, 1901, 1902 and 1906. Migrants begin to arrive in the fall about September 20. They are common from the last of September to the middle of October. The latest fall record is a female killed October 25, 1899.

57. Family Aluconidæ. The Barn Owls.

214 (365). **Aluco pratincola** (Bonaparte). Barn owl.

The barn owl has been recorded within the basin at various intervals since 1880 at which time Foster Parker reports one taken at Cayuga. On December 13, 1885, one was taken at Auburn by F. J. Stupp. Another was taken by L. O. Asbury September 23, 1900, at Sennett and on December 1, 1904, a specimen was shot near South Danby. Mr. Samuel Tisdel, of Ithaca, has in his possession a mounted specimen taken near Ithaca in the fall of 1907. He states that during the fall of that year three others taken near Ithaca were brought to his shop to be mounted. On June 6, 1908, A. A. Allen and J. T. Lloyd saw one in the Renwick Marshes. November 27, 1908, one was killed in Michigan Hollow in the extreme southern portion of the basin. There is little doubt that this species is increasing in the lake basin.

58. Family Strigidæ. The Owls.

215 (366). **Asio wilsonianus** (Lesson). Long-eared owl.

Common permanent resident. The only breeding record which we have is a nest containing eggs found April 9, 1905.

216 (367). **Asio flammeus** (Pontoppidan). Short-eared owl.

A resident species. Common in summer at the north end of the basin, uncommon in the southern portion.

217 (368). **Stryx varia** Barton. Barred owl.

Uncommon resident.

218 (372). **Cryptoglaux acadicus** (Gmelin). Saw-whet owl.

Rare. "Adult male taken July 18, 1878. Two specimens received, taken in Cayuga Co., April 14, 1877, and November, 1878" ("Auburn List," p. 27). A female was taken at Sennett January 25, 1904, by Charles Lyon and one was taken at Ithaca January 16, 1908, by A. A. Allen and J. T. Lloyd.

219 (373). **Otus asio** (Linnæus). Screech owl.

Abundant permanent resident.

220 (375). **Bubo virginianus** (Gmelin). Great horned owl.

Uncommon permanent resident.

221 (376). **Nyctea nyctea** (Linnæus). Snowy owl.

Irregular winter visitant. In the collection of Cornell University are three specimens from this basin taken as follows: winter of 1878 at Aurora, December 12, 1890, at Covert, February 22, 1902 at Newfield.

222 (377*a*). **Surnia ulula caparoch** (Müller). Hawk owl.

The only record of this species is a male taken by L. O. Ashbury at Conquest, November 23, 1902. Two birds were seen and one captured.

XXXIV. Order COCCYGES. The Cuckoo-like Birds.

59. Family CUCULIDÆ. The Cuckoos.

223 (387). **Coccyzus americanus** (Linnæus). Yellow-billed cuckoo.

Common summer resident. The average date of spring arrival is May 10, the earliest, May 6, 1905.

224 (388). **Coccyzus erythrophthalmus** (Wilson). Black-billed Cuckoo.

Common summer resident. The average date of spring arrival is May 9, the earliest, April 24, 1904.

60. Family ALCEDINIDÆ. The Kingfishers.

225 (390). **Ceryle alcyon** (Linnæus). Belted kingfisher.

Common summer resident. On December 23, 1874, a female was taken at Ithaca and on January 15, 1905, one individual was seen near an open stream in the Renwick wood at Ithaca. The average date of spring arrival is April 4, the earliest, March 17, 1907. It is common in the fall until the middle of October. By the 25th of this month all have usually disappeared.

XXXV. Order PICI. The Woodpeckers.

61. Family PICIDÆ. The Woodpeckers.

226 (393). **Dryobates villosus** (Linnæus). Hairy woodpecker.

Common resident species.

227 (394*c*). **Dryobates pubescens medianus** (Swainson). Downy woodpecker.

Common permanent resident. The active season of nesting is from May 10 to June 15. The earliest record of nesting is May 6, 1904. Our earliest record of young on the wing is June 9, 1904.

228 (400). **Picoides articus** (Swainson). Arctic three-toed woodpecker.

An occasional winter visitant. Specimens were taken at Ithaca during the winter of 1895–6 and on November 1, 1901, by L. A. Fuertes. A female was taken October 19, 1901, at Sennett by L. O. Ashbury.

229 (402). **Sphyrapicus varius** (Linnæus). Yellow-bellied sapsucker.

Common transient and "reported as breeding in Cayuga, Yates and Oneida Counties" (Eaton). The average date of spring arrival is April 10, the earliest, March 30, 1908. They become common the last of April and the first of May. The latest date upon which individuals have been seen at Ithaca is May 26, 1900. Usually all have left by May 15. They appear in the fall from September 20 to November 1. The latest fall record is one seen November 27, 1908.

230 (406). **Melanerpes erythrocephalus** (Linnæus). Red-headed woodpecker.

Rare in winter but becomes common about May 5. The only nesting records which we have are eggs found June 13, 1903, and May 16, 1907.

231 (409). **Centurus carolinus** (Linnæus). Red-bellied woodpecker.

Rare. There are in the collection of Cornell University three specimens taken near Ithaca. One in 1850, another in 1858 and a third taken by L. A. Fuertes in November, 1894. Mr. G. C. Embody took a female in a small swamp just north of Auburn, March 4, 1898.

232 (412*a*). **Colaptes auratus luteus** Bangs. Northern flicker.

Common summer resident and occasionally present in winter.

Migrants begin to arrive the last of March from which time it is common until October 20. Frequently many are seen as late as the first of December.

XXXVI. Order MACROCHIRES. The Goatsuckers, Swifts and Hummingbirds.

62. Family CAPRIMULGIDÆ. The Goatsuckers.

233 (417). **Antrostomus vociferus** (Wilson). Whip-poor-will.

Common summer resident in the basin from May 1 to September 1. In the region about Ithaca it is very uncommon. The latest that it has been observed in the fall is October 7, 1907. The earliest spring record is April 29, 1906.

234 (420). **Chordeiles virginianus** (Gmelin). Nighthawk.

Common summer resident. The average date of spring arrival is May 19, the earliest, May 15, 1906.

63. Family MICROPODIDÆ. The Swifts.

235 (423). **Chaetura pelagica** (Linnæus). Chimney swift.

Abundant summer resident. The average date of spring arrival is April 23, the earliest, April 19, 1889. Nests with eggs are found from May 20 to July 5. Usually all have departed in the fall by October 1.

64. Family TROCHILIDÆ. The Hummingbirds.

236 (428). **Archilochus colubris** (Linnæus). Ruby-throated hummingbird.

Common summer resident from May 10, the average date of spring arrival, to September 10. Nesting dates all fall between May 23 and July 21. The crest of the nesting season is between June 15 and 30.

XXXVII. Order PASSERES. The Perching Birds.

65. Family TYRANNIDÆ. The Flycatchers.

237 (444). **Tyrannus tyrannus** (Linnæus). Kingbird.

Common summer resident. The average date of spring arrival is May 6, the earliest, May 3, 1902. They nest the very last of May and during June.

238 (452). **Myiarchus crinitus** (Linnæus). Crested flycatcher.

Common summer resident. The average date of spring arrival is May 4, the earliest, May 1, 1900. Nesting begins the last of May and lasts through June.

239 (456). **Sayornis phoebe** (Latham). Phœbe.

Abundant summer resident along the streams and lake shores. The average date of spring arrival is March 20, the earliest, March 9, 1899. During the first half of October they depart for the south, latest record being October 19, 1902. Nesting begins April 20 and continues through May and June. The earliest nesting record is April 13, 1901. The latest date for eggs is a nest found June 21, 1900.

240 (459). **Nuttallornis borealis** (Swainson). Olive-sided flycatcher.

Rare. A specimen was taken in Fall creek gorge by L. A. Fuertes May 11, 1905. G. C. Embody took a male at the north end of the lake May 30, 1898.

241 (461). **Myiochanes virens** (Linnæus). Wood pewee.

Abundant summer resident. The average date of spring arrival is May 13, the earliest, May 1, 1900. They nest throughout the month of June.

242 (463). **Empidonax flaviventris** Baird. Yellow-bellied flycatcher.

The definite records are three specimens, two males and one female taken at Ithaca by R. B. Hough on May 29, 1882, and several taken in the vicinity of Waterloo and reported by E. H. Eaton. A few are reported *seen* each year between May 15 and June 10.

243 (466*a*). **Empidonax traillii alnorum** Brewster. Alder flycatcher.

Uncommon transient and rare summer resident. The average date of spring arrival is May 14, the earliest, May 4, 1905. The yellow-bellied and the alder are the last flycatchers to arrive in the spring, the latter loitering along into June. In 1906 it was found until June 9 in the willow and alder thickets along the west side of the Renwick marshes. L. A. Fuertes reports it as breeding at Cay-

uta, N. Y., just outside the Cayuga basin on the southwest. A. A. Allen and J. T. Lloyd found a nest containing two eggs on June 16, 1908, at Ithaca.

244 (467). **Empidonax minimus** Baird. Least flycatcher.

Abundant summer resident. The average date of spring arrival is May 4, the earliest, May 1, 1906. Abundant everywhere except the denser wooded areas.

66. Family Alaudidæ. The Larks.

245 (474). **Otocoris alpestris** (Linnæus). Shore lark.

It is reported by Mr. Fuertes that the shore lark was formerly common in this basin. It is now replaced by the prairie horned lark. A few are, however, still found in winter. Mr. G. C. Embody took two specimens at Auburn.

246 (474*b*). **Otocoris alpestris praticola** Henshaw. Prairie horned lark.

Permanent resident although not common during December and January. They become common about the first of February. This species is the first of our Passerine birds to nest. On April 7, 1904, a nest was found at Trumansburg which contained one egg and two young. Dating back fourteen days, which, according to Bendire is the period of incubation, the eggs must have been laid not far from March 20 to 23. On April 20, 1902, there was taken at Ithaca a young individual which had just left the nest. On April 6, 1906, young just beginning to fly were seen. In 1907 Mr. A. A. Allen found on April 3 a nest containing eggs and on April 4 another nest in which the eggs hatched April 10. The young of this nest were killed by a very heavy snow storm a few days later.

67. Family Corvidæ. The Crows and Jays.

247 (477). **Cyanocitta cristata** (Linnæus). Blue jay.

Common permanent resident. It is now rarely seen in the vicinity of Ithaca except for a short period during the spring and fall. It has not been known to nest in this immediate vicinity since 1889 when a pair built in a small grove of oaks on the Cornell Campus.

In all other portions of the basin they are fairly common. At Enfield on May 5, 1907, A. A. Allen found a nest containing five eggs.

248 (486a). **Corvus corax principalis** Ridgway. Northern raven.

"Formerly not uncommon at the north end of the basin. The last reported was one, seen by Foster Parker in 1880, pursued by a number of crows." (Eaton).

249 (488). **Corvus brachyrhynchos** C. L. Brehm. Crow.

Common permanent resident. Nests containing eggs are most commonly found from April 10 to 20. In 1903 a nest containing eggs was found on April 3. The latest record of nest and eggs is May 16, 1900.

68. Family Icteridæ. The Blackbirds and Orioles.

250 (494). **Dolichonyx oryzivorus** (Linnæus). Bobolink.

Common summer resident. The average date of spring arrival is May 4, the earliest, April 30, 1900. By July 10 they are gathered in large flocks in the marshes where they remain through August and the first of September, at about the middle of which they depart for the south.

251 (495). **Molothrus ater** (Boddaert). Cowbird.

Abundant summer resident. The average date of spring arrival is March 28, the earliest, March 14, 1899. Eggs are found from May 5 to June 15. The maximum period of egg-laying is the last half of May. The phœbe, the vireos, redstart and yellow warbler are the most common victims of the cowbird's parasitic habits.

252 (498). **Agelaius phœniceus** (Linnæus). Red-winged blackbird.

Common summer resident and found regularly in small numbers in the marshes during winter. Migration begins about March 10. The earliest record is a large flock of males in full song, seen February 22, 1902. The earliest record of nesting is May 12, 1906. The most active breeding period is from the middle of May to the first of June. Young are on the wing by June 5. During the first two weeks of July this species collects in large flocks in the marshes where they remain until the last of November. Flocks containing hundreds are seen migrating all through November. So far as they have been observed at Ithaca they follow the inlet valley towards the south.

253 (501). **Sturnella magna** (Linnæus). Meadow lark.

Common summer resident and found regularly in small numbers in winter. The average date of the spring arrivals is March 17, the earliest, March 4, 1906. They remain common until the last of October.

254 (506). **Icterus spurius** (Linnæus). Orchard oriole.

Rare. On May 30, 1898, G. C. Embody took a male at Cayuga. On May 27, 1899, Burdett Wright found a pair nesting at Montezuma. A male was taken at Ithaca, May 3, 1890, by L. A. Fuertes. who saw a pair at Ithaca, June 7, 1902. A male in song was found May 18, 1908, in the Inlet valley just south of Ithaca and in the same locality A. A. Allen and J. T. Lloyd found a nest which contained four eggs and one young.

255 (507). **Icterus galbula** (Linnæus). Baltimore oriole.

Common summer resident. The average date of spring arrival is May 3, the earliest, April 30, 1900 and 1905. They nest from May 10 to June 1.

256 (509). **Euphagus carolinus** (Müller). Rusty blackbird.

Common transient. It arrives usually the last days of March. The earliest date is March 18, 1901. It is common from April 15 to 30 but small flocks are seen until May 15.

257 (511*b*). **Quiscalus quiscula aeneus** (Ridgway). Bronzed grackle.

Common summer resident and occasionally found in winter. The average date of spring arrival is March 14, the earliest, March 4, 1906. Nesting begins the last half of April and continues throughout May. By May 25 large numbers of young are on the wing; during the first week in June this species begins to collect in flocks and resort to common roosts.

69. Family FRINGILLIDÆ. The Sparrows.

258 (514). **Hesperiphona vespertina** (W. Cooper). Evening grosbeak.

Accidental visitant. During the winter of 1890 when it was so common in New England it appeared here in fairly large numbers

from January 22, when first seen, to March 28. They were not seen again until April 11, 1904, when L. A. Fuertes shot a pair on the Cornell Campus. On December 8, 1906, Mrs. A. T. Kerr reported one which she saw on Cornell Heights.

259 (515). **Pinicola enucleator leucura** (Müller). Pine grosbeak.

An irregular winter and spring visitant but never common. In 1890 it was reported by L. A. Fuertes on January 23. Since that date it has been recorded as follows: 1904 on January 7, April 26 and 29 and May 5. In 1905, April 20. In 1906, March 5.

260 (517). **Carpodacus purpureus** (Gmelin). Purple finch.

Common summer resident from March 22 to November 10. It is occasionally seen in winter. It nests during May and June. The latest date of nest and eggs is June 21, 1905.

261. **Passer domesticus** (Linnæus). English sparrow.

Abundant.

262 (521). **Loxia curvirostra minor** (Brehm). Red crossbill.

An irregular visitant. Although commonly seen during March and April they are frequently present during late spring and summer. In 1889 L. A. Fuertes reported them on June 16. In 1900 T. L. Hankinson saw a flock of 30 individuals on May 30 and again on July 15. On August 7 of this year another flock was seen. In 1906 a flock of ten were seen on the Cornell Campus from June 21 to 24. In 1907 they were first seen on May 27 and continued common until June 24. In 1908 they were seen daily from June 10 to 16.

263 (522). **Loxia leucoptera** Gmelin. White-winged crossbill.

Rare winter visitant. During the winter of 1907 this species was more common in the basin than in any year since records have been kept. Specimens were frequently taken and seen from January 5 to the first of March. The last specimen recorded that year was one killed at Taughannock Falls, March 4. November 15, 1882, a female was taken at Ithaca. L. A. Fuertes took a specimen at Ithaca, February 8, 1906.

264 (528). **Acanthis linaria** (Linnæus). Redpoll.

An irregular winter visitant but usually common when present. There are no records of their occurrence before January in any year.

There is a specimen of a female in the collection of Cornell University taken at Ithaca in January, 1876, showing that they were present that winter but no notes to indicate whether or not they were common. On January 10, 1879, a male was killed by R. B. Hough. They were reported by E. H. Eaton as common that winter in Cayuga Co. In 1904 they were common all through January, February and March on the twenty-ninth of which L. A. Fuertes shot a specimen from a large flock. In 1907 they were common from January 13 to March 24. In 1909 the first individuals appeared January 5 and were common everywhere in the southern portion of the basin until February 1.

265 (529). **Astragalinus tristis** (Linnæus). Goldfinch.

Permanent resident although more or less irregular in winter. They become common in the spring from the tenth to the fifteenth of April. The breeding plumage begins to show about April 20 and is complete about the middle of May at which time the males are in full song. Nests and eggs are commonly found during July.

266 (533). **Spinus pinus** (Wilson). Pine siskin.

An uncommon winter and a common spring visitant from the last of April to the middle of May. The latest spring record is May 30, 1907. The earliest winter record is a specimen taken January 20, 1890.

267 (534). **Plectrophenax nivalis** (Linnæus). Snow bunting.

Common winter resident being most common from January to March. In the fall they arrive the last week in October and remain until the middle of March. The latest date is March 26, 1890.

268 (536). **Calcarius lapponicus** (Linnæus). Lapland longspur.

Rare. Mr. Fred Allen took a specimen near Auburn during the winter of 1876 and Mr. Charles Lyon took a male near Auburn, March 3, 1899.

269 (540). **Poœcetes gramineus** (Gmelin). Vesper sparrow.

Common summer resident. The average date of spring arrival is March 28, the earliest, March 23, 1903. The active breeding period is May and June. The earliest record of nest and eggs is April 25, 1900, the latest, July 23, 1900. This species remains in the fall until the last of October. The latest fall record is November 27, 1908.

270 (542*a*). **Passerculus sandwichensis savanna** (Wilson). Savannah sparrow.

Common summer resident. The average date of spring arrival is April 6, the earliest, March 23, 1905. About July 25 this species begins to collect in flocks which become numerous the first of October. All have left usually by the middle of the month.

271 (546). **Ammodramus savannarum australis** Maynard. Grasshopper sparrow.

Common summer resident. The average date of spring arrival is May 2, the earliest, April 26, 1905.

272 (548). **Passerherbulus lecontei** (Audubon). Leconte's sparrow.

One specimen was shot in the Renwick marshes by L. A. Fuertes, October 11, 1897.

273 (549.1). **Passerherbulus nelsoni** (Allen). Nelson's sparrow.

The numerous specimens taken since 1900 justify the conclusion that this species is a common visitant during the fall migration from the middle of September to the first of October. They have always been found in the rushes close to the water where they skulk and run in a fashion very suggestive of a mouse. When flushed they rise for a moment and disappear again much as a wren.

274 (549.1*a*). **Passerherbulus nelsoni subvirgatus** (Dwight). Acadian sharp-tailed sparrow.

Uncommon but regular fall visitant. It arrives the very last of September or first of October, about a week later than the Nelson's sparrow and remains for a period of from 12 to 15 days. Neither this nor the preceding species has ever been taken in the spring. The definite records are skins, which are now in the collection of L. A. Fuertes and that of Cornell University, taken between September 26 and October 12.

275 (554). **Zonotrichia leucophrys** (Forster). White-crowned sparrow.

Common transient. The average date of spring arrival is May 4, the earliest, May 2, 1907. It remains until May 20 becoming common from the tenth to the fifteenth of the month. It is common in the fall during the very last of September and the first half of Octo-

ber. The latest record is October 28, 1908. A single individual was seen in the marshes at Ithaca, February 24, 1906.

276 (558). **Zonotrichia albicollis** (Gmelin). White-throated sparrow.

Common transient. The average date of spring arrival is April 17, the earliest, April 13, 1903. They become common the last week of April and remain until May 20. The latest record is May 23, 1908. In the fall they appear about September 20 and are common throughout October. The latest record for the fall is November 4, 1908.

277 (559). **Spizella monticola** (Gmelin). Tree sparrow.

Common winter resident. They arrive October 1 and remain common until April 25. A few stragglers have been noted after this date. In 1889 L. A. Fuertes saw several on May 8. In 1904 a few were seen on May 2 and in 1906 the latest date was April 30.

278 (560). **Spizella passerina** (Bechstein). Chipping sparrow.

Common summer resident. The average date of spring arrival is April 2, the earliest March 27, 1907. The maximum nesting period is from May 15 to June 30. They remain in the fall until the last week in October. The latest record is November 1, 1902.

279 (563). **Spizella pusilla** (Wilson). Field sparrow.

Common summer resident. The average date of spring arrival is March 30, the earliest, March 25, 1907. The nesting period extends from May 15 to June 5. They remain in the fall until the very last of October.

280 (567). **Junco hyemalis** (Linnæus). Slate-colored junco.

A common transient, uncommon winter resident and a rare summer resident. They become common in the fall the last week in September and are abundant during October. In the spring the first influx from the south occurs the last week in March. They remain abundant throughout April. The first of May there is a decided reduction in numbers and by May 10 the migration ceases. On June 21, 1878, F. H. King[28] found two individuals in the Enfield gorge. In 1907, each day from July 21 to 25, two individuals were

[28] *Bull. Nutt. Orn. Club,* Vol. III., p. 195.

seen in the same locality. A. A. Allen and J. T. Lloyd found two adults and three young just leaving the nest, June 19, 1908, at the source of Cascadilla Creek.

281 (581). **Melospiza melodia** (Wilson). Song sparrow.

Common summer resident and not uncommon in the marshes during winter. Migrants from the south begin to arrive about March 10. For the remainder of the month this species is abundant. The nesting season extends from May 1 to July 22. A few nests have been found the last of April.

282 (583). **Melospiza lincolni** (Audubon). Lincoln's sparrow.

An uncommon but regular transient. It arrives the very last of April, the twenty-seventh being the earliest date. It is met with occasionally until May 15. It appears in the fall the last of September or first of October.

283 (584). **Melospiza georgiana** (Latham). Swamp sparrow.

Common summer resident. It is occasionally taken in the marshes in winter. The average date of spring arrival is April 12, the earliest, March 29, 1904. During the second week in October there is a decided reduction in numbers and all have left before the last of the month.

284 (585). **Passerella iliaca** (Merrem). Fox sparrow.

Common transient. The average date of spring arrival is April 15, the earliest, March 17, 1908. They are very rarely found after April 15, the latest being May 8, 1908. In the fall they appear the first week in October and are found until the first week in November. The latest date is November 15, 1908.

285 (587). **Pipilo erythrophthalmus** (Linnæus). Towhee.

Common transient and an uncommon but regular summer resident. The average date of spring arrival is April 23, the earliest, April 18, 1905. It is found nesting in a few localities, at the south end of the basin, from May 25 through the larger part of June. Young on the wing have been seen June 19. They remain in the fall until October 20.

286 (595). **Zamelodia ludoviciana** (Linnæus). Rose-breasted grosbeak.

Common summer resident. The average date of spring arrival is May 6, the earliest, April 30, 1900. Eggs have been found from May 16 to June 9. They remain in the fall until the last of September. The latest date is October 1, 1908.

287 (598). **Passerina cyanea** (Linnæus). Indigo bunting.

Common summer resident. The average date of spring arrival is May 14, the earliest, May 6, 1902. Eggs have been found from June 7 to July 15. Usually the middle of September marks the limit of their stay in this basin although a few have been seen after that date. October 1, 1908, is the latest date.

288 (604). **Spiza americana** (Gmelin). Dickcissel.

This species nested in the town of Jamaica, Seneca Co., in 1875. One of the specimens taken at that time is now in the collection of E. H. Eaton.

70. Family TANAGRIDÆ. The Tanagers.

289 (608). **Piranga erythromelas** Vieillot. Scarlet tanager.

Common summer resident. The average date of spring arrival is May 8, the earliest, May 6, 1906. Nesting begins the last week in May and continues through the first half of June. A few nests with eggs have been found in the latter part of June and one as late as July 9 (1906). This species has steadily increased in numbers since 1899. It remains in the fall until the middle of September, the 21st of this month constituting the latest record.

71. Family HIRUNDINIDÆ. The Swallows.

290 (611). **Progne subis** (Linnæus). Purple martin.

Rare although formerly very common. Two were seen at Ithaca April 26 and 27, 1905. One was seen at Taughannock Falls, June 3, 1906. It is still found in small numbers in the northern portion of the basin.

291 (612). **Petrochelidon lunifrons** (Say). Cliff swallow.

Formerly a common summer resident but rapidly decreasing in numbers. The average date of spring arrival is April 25, the ear-

liest, April 20, 1900 and 1905. It nests through June and departs the very last of August.

292 (613). **Hirundo erythrogaster** Boddaert. Barn swallow.

Common summer resident. The average date of spring arrival is April 19, the earliest, April 13, 1905. This species along with individuals of the preceding begin to collect in large flocks in the marshes about July 15. The latest fall record is September 26, 1908.

293 (614). **Iridoprocne bicolor** (Vieillot). Tree swallow.

Common summer resident and abundant during migration. The average date of spring arrival is April 2, the earliest, March 23, 1907. Nests with eggs have been found from May 8 to June 15. It becomes abundant the last of September, suddenly disappearing about October 15. In 1906 large flocks were common until October 13. In 1907 numerous flocks were seen until October 12.

294 (616). **Riparia riparia** (Linnæus). Bank swallow.

Common summer resident. The average date of spring arrival is April 25, the earliest, April 14, 1906. Nesting begins May 10 and lasts until June 15. The nests are found usually in gravelly or sandy banks. The larger proportion of individuals leave during the first week in September. Our latest record is September 26, 1908.

295 (617). **Stelgidopteryx serripennis** (Audubon). Rough-winged swallow.

Common summer resident. The average date of spring arrival is April 26, the earliest, April 22, 1906. Nests and eggs have been found from May 10 to June 10. This species is not so partial to sand and gravel banks as the preceding. They are often found nesting in shale banks along the lake shore, in the crevices of rocks in the gorges and in banks of loose earth. Frequently we find them nesting in isolated pairs and always the colonies are smaller than those of the Bank Swallow. As a rule all have left by September 10. The latest date is a specimen taken September 26, 1908.

72. Family BOMBYCILLIDÆ. The Waxwings.

296 (619). **Bombycilla cedrorum** Vieillot. Cedar waxwing.

Common summer resident and frequently seen in small flocks

during winter. They are more or less irregular at all seasons except mid-summer. Nests with eggs have been found from June 15 to August 8.

73. Family LANIIDÆ. The Shrikes.

297 (621). **Lanius borealis** Vieillot. Northern shrike.

Occasional winter visitant, most often seen in January and February. The earliest record of this species in the fall is November 8, 1875, and November 25, 1908. The latest spring record is February 24, 1905.

298 (622*e*). **Lanius ludovicianus migrans** W. Palmer. Northern loggerhead shrike.

An uncommon but regular spring migrant. The average date of arrival is March 24, the earliest, March 17, 1907. The latest date upon which it has been seen is May 24, 1904. "A nest with six eggs was found at Ithaca in May, 1877, by A. R. Ingersoll" (C. J. Pennock).

74. Family VIREONIDÆ. The Vireos.

299 (624). **Vireosylva olivacea** (Linnæus). Red-eyed vireo.

Common summer resident. The average date of spring arrival is May 5, the earliest, April 30, 1906. The nesting season extends from May 30 to July 1. It remains in the fall until the last week in September.

300 (626). **Vireosylva philadelphica** Cassin. Philadelphia vireo.

Rare. Three specimens have been taken within the basin as follows: a male May 16, 1906, and a female September 21, 1907, both in the collection of L. A. Fuertes, and a specimen, taken October 1, 1908, in the collection of Cornell University.

301 (627). **Vireosylva gilva** (Vieillot). Warbling vireo.

Common summer resident. The average date of arrival in spring is May 2, the earliest, April 27, 1908. Nests with eggs are found from May 12 to June 10. It departs in the fall about the middle of September. An individual seen on September 19, 1908, is the latest record.

302 (628). **Lanivireo flavifrons** (Vieillot). Yellow-throated vireo.

Common summer resident. The average date of spring arrival

is May 3, the earliest, April 30, 1905 and 1906. Nesting begins May 20 and lasts until June 15. This species is seldom seen after the first week in September. L. A. Fuertes shot a specimen September 26, 1889.

303 (629). **Lanivireo solitarius** (Wilson). Blue-headed vireo.

Common transient and a rare summer resident. The average date of arrival is May 4, the earliest, April 25, 1906. It is not common after May 15 but a few have been seen between this date and May 28. In 1893 L. A. Fuertes found a pair breeding in the Cascadilla Woods near Ithaca. In the fall it is found throughout September. The latest fall date is October 6, 1907.

75. Family MNIOTILTIDÆ. The Wood Warblers.

304 (635). **Mniotilta varia** (Linnæus). Black and white warbler.

Common transient and occasionally found breeding. The average date of spring arrival is April 30, the earliest, April 26, 1905. The bulk of migrants have passed by May 18. On June 13, 1902, T. L. Hankinson found a nest containing five young at North Spencer, about a mile outside the lake basin on the south. June 19, 1908 A. A. Allen found young just taking wing near the source of Cascadilla Creek. L. A. Fuertes reports it as breeding on Snyder Hill. Migrants are common in the fall from July 13 to September 1.

304*a* (639). **Helmitheros vermivorus** (Gmelin). Worm-eating warbler.

The only record of this species in the basin is an adult male taken by A. A. Allen, May 6, 1909, at Ithaca.

305 (642). **Vermivora chrysoptera** (Linnæus). Golden-winged warbler.

Mr. F. S. Wright, of Auburn, has taken specimens at the north end of the basin as follows: June 6, 1883, an adult male on Howland Island; May 13, 1898, an adult male at Sennett, N. Y.; May 25, 1901, an adult male on Howland Island; May 5, 1902, an adult male on Howland Island. Two other specimens have been taken in that vicinity but we do not have the data.

306 (645). **Vermivora rubricapilla** (Wilson). Nashville warbler.

Common transient. A few breed on South Hill near Ithaca. The average date of spring arrival is May 3, the earliest April 28, 1908. The migration is over by May 20. On May 27, 1905, a nest with five eggs was found on South Hill and on June 6, 1906, in the same locality a nest containing five young. The latest fall date is September 19, 1908, when it was still common.

307 (646). **Vermivora celata** (Say). Orange-crowned warbler.

Rare. An adult male was taken May 17, 1900, near Auburn by Charles Lyon. On October 6, 1907, a specimen was taken at Ithaca by L. A. Fuertes. There are two specimens in the collection of Cornell University taken at Ithaca, one October 6, 1907, the other, October 12 of the same year. On May 11, 1909, Mr. A. A. Allen killed an adult male at Ithaca and on May 12 saw four more.

308 (647). **Vermivora peregrina** (Wilson). Tennessee warbler.

Common transient. The average date of spring arrival is May 15, the earliest, May 10, 1908. It is not found after May 30.

309 (648*a*). **Compsothlypis americana usneæ** Brewster. Northern parula warbler.

Common transient. The average date of arrival in spring is May 6, the earliest, April 30, 1905. It has been found breeding on the Cornell University Campus and on South Hill. The latest fall date is October 1, 1900.

310 (650). **Dendroica tigrina** (Gmelin). Cape May warbler.

Common transient. The average date of arrival in spring is May 13, the earliest, May 10, 1899. The migration of this species lasts for a few days only. None have been noted later than May 20 but very frequently are common up to this date.

311 (652). **Dendroica æstiva** (Gmelin. Yellow warbler.

Common summer resident. The average date of spring arrival is April 28, the earliest, April 25, 1908. It nests from May 13 to June 1. The latest date on which it has been noted in the fall is September 21.

312 (654). **Dendroica caerulescens** (Gmelin). Black-throated blue warbler.

Common transient. It breeds regularly in small numbers on South and Snyder hills. The average date of spring arrival is May 3, the earliest, April 29, 1905. Nesting continues through June and the first half of July. The latest record in this connection is a nest, found on August 11, which the young were just leaving. This species is found in the fall until the middle of October.

313 (655). **Dendroica coronata** (Linnæus). Myrtle warbler.

Common transient. The average date of arrival in spring is April 22, the earliest, April 14, 1904. The migration of this species ceases usually about May 15. After this date only a straggler is seen. The latest record is May 21, 1904. The fall migration begins the middle of September, becoming common about the first of October. From the middle of this month they gradually diminish in numbers finally disappearing about October 20. The latest fall record is October 28, 1908.

314 (657). **Dendroica magnolia** (Wilson). Magnolia warbler.

Common transient. A few breed regularly in the southern portion of the basin. The average date of spring arrival is May 6, the earliest, April 27, 1902. Migrants remain in the basin as late as May 30. On July 8, 1906, A. A. Allen found, on South Hill, a nest containing eggs. The young left this nest on July 14. In the vicinity of South Hill this species has been seen on the following dates: 1905, June 4; 1906, June 7, July 30, August 1; 1907, July 22, two immature birds. On May 30, 1909, a nest containing two eggs was found on the hills near Michigan Hollow in the southern portion of the basin.

315 (658). **Dendroica caerulea** (Wilson). Cerulean warbler.

Uncommon but regular transient. It breeds on Howland Island at the north end of the lake. The average date of spring arrival is May 10, the earliest, May 2, 1902.

316 (659). **Dendroica pennsylvanica** (Linnæus). Chestnut-sided warbler.

Common transient and not uncommon summer resident. The average date of arrival is May 18, the earliest, May 3, 1905. Nests

with eggs have been found on South Hill from May 25 to June 20. On July 8, 1906, a nest of young were just taking wing. The latest fall record is September 19, 1908.

317 (660). **Dendroica castanea** (Wilson). Bay-breasted warbler.

Common transient. The average date of arrival is May 11, the earliest, May 7, 1905. The bulk of migrants have passed before May 25. The latest record is May 30, 1907. "I have found it breeding in the immediate vicinity of Cayuga Lake" (Audubon).[29]

318 (661). **Dendroica striata** (Forster). Black-poll warbler.

Common transient. The average date of spring arrival is May 16, the earliest, May 10, 1905. It is common from its arrival to May 30. A few are seen always during the first week of June, the latest record being June 9, 1907. In the fall it is present from September 10 to October 20 and is most common from September 25 to October 10.

319 (662). **Dendroica fusca** (P. L. S. Müller). Blackburnian warbler.

Common transient and regular but uncommon summer resident. The average date of arrival is May 4, the earliest, April 30, 1908, and May 1, 1900, 1905 and 1906. The migration ceases about May 20. On June 13, 1900, L. A. Fuertes first found them breeding on Snyder Hill. Since that date they have been found to breed regularly there and on South Hill.

320 (667). **Dendroica virens** (Gmelin). Black-throated green warbler.

Abundant transient and common summer resident. The average date of arrival is May 2, the earliest, April 25, 1908. Eggs have been found from June 5 to July 8. It is abundant all through September and disappears the first week in October. The latest date is October 7.

321 (671). **Dendroica vigorsi** (Audubon). Pine warbler.

Common transient and common locally during the summer. The average date of arrival is April 14, the earliest, April 2, 1905. No nests of this species have been found but it is common in growths of pine during May, June, July and a part of August.

[29] "Ornithological Biography," Vol. I., p. 447, 1831.

322 (672). **Dendroica palmarum** (Gmelin). Palm warbler.

Not a common but a regular transient. The average date of arrival is May 2, the earliest, April 27, 1908. The latest record for spring is May 21, 1908.

323 (672*a*). **Dendroica palmarum hypochrysea** Ridgway. Yellow palm warbler.

One specimen, taken October 25, 1908, at Danby.

324 (674). **Seiurus aurocapillus** (Linnæus). Oven-bird.

Common summer resident. The average date of arrival is May 3, the earliest, April 27, 1908. Nests with eggs are found from May 25 to June 20. The bulk of individuals have left for the south by September 15. The latest fall date is October 1, 1908.

325 (675). **Seiurus noveboracensis** (Gmelin). Water-thrush.

Common transient and breeds in small numbers. The average date of spring arrival is April 30, the earliest, April 27, 1908. They cease to be common about May 5. They breed in small numbers at the base of West Hill and in a small marsh on East Hill near Ithaca. In the fall they become common the first week in August and remain until October 1.

326 (676). **Seiurus motacilla** (Vieillot). Lousiana water-thrush.

Common summer resident. The average date of spring arrival is April 16, the earliest, April 14, 1906. Nests with eggs are found from May 7 to June 3. On June 13, 1906, L. A. Fuertes found four young just leaving the nest.

327 (678). **Oporornis agilis** (Wilson). Connecticut warbler.

Common transient in the fall from September 7 to 30. Not present in the spring.

328 (679). **Oporornis philadelphia** (Wilson). Mourning warbler.

Common transient and frequently found during summer. The average date of arrival is May 10, the earliest, May 4, 1905. No nests of this species have been found but males in full song are seen every year in the woods of Renwick marsh through May, June and July. On June 30, 1908, immature birds were seen in the Renwick woods.

329 (681). **Geothlypis trichas** (Linnæus). Maryland yellow-throat.

Common summer resident. The average date of arrival is May 4, the earliest, April 30, 1905. Nests with eggs are found from May 25 to June 20. It ceases to be common in the fall about the first of October. The latest date is October 10.

330 (683). **Icteria virens** (Linnæus). Yellow-breasted chat.

Fairly common summer resident. The average date of arrival is May 12, the earliest, May 4, 1905. Nest-building begins about May 25. Eggs are found throughout June. On June 26, 1902, L. A. Fuertes found a pair just beginning to build. Formerly this species was rare in the region about the south end of the lake but has increased greatly during the past eight years.

331 (684). **Wilsonia citrina** (Boddaert). Hooded warbler.

Rare transient and summer resident at the north end of the lake. It is found between May 8 and 20, but appears to be more common from the tenth to the fifteenth of the month. Mr. G. C. Embody reports a nest with young which he found near Auburn and Mr. F. S. Wright reports one found four miles east of Auburn.

332 (685). **Wilsonia pusilla** (Wilson). Wilson's warbler.

Common transient. The average date of arrival is May 11, the earliest, May 10, 1900. It is common from its arrival until the twentieth of the month. A few are sometimes seen after this date. The latest date is one seen June 7, 1908.

333 (686). **Wilsonia canadensis** (Linnæus). Canadian warbler.

Common transient. It breeds in small numbers on the hills in the southern portion of the basin. The average date of arrival is May 8, the earliest, May 5, 1905. They continue common from their arrival until May 30. They have been found breeding on South Hill and Ellis Hollow from June 7 to 19. On the latter date a nest of five young were found.

334 (687). **Setophaga ruticilla** (Linnæus). Redstart.

Common summer resident. The average date of arrival is May 3, the earliest, April 29, 1905 and 1906. They nest from May 10 to June 15. A few are found nesting later than this date. On July 11, 1906, a nest was found which contained eggs. This species

departs the first of September. The latest date is September 10, 1890.

76. Family MOTACILLIDÆ. The Wagtails.

335 (697). **Anthus rubescens** (Tunstall). Titlark.

Common transient from April 7 to May 15 and from September 20 to October 20.

77. Family MIMIDÆ. The Thrashers and Mockingbirds.

336 (704). **Dumetella carolinensis** (Linnæus). Catbird.

Common summer resident. The average date of arrival is May 5, the earliest, April 27, 1908. Breeding occurs through the last half of May and whole of June. The majority of individuals have left in the fall by September 30 but a few are seen always during the first days of October. The latest date is October 8, 1908.

337 (705). **Toxostoma rufum** (Linnæus). Brown thrasher.

Common transient and an uncommon summer resident. The average date of arrival is May 1, the earliest, April 27, 1908. The migration lasts for about two weeks, ceasing as a rule about May 15. A few breed regularly on South and Snyder Hills. The latest fall date is October 6, 1900.

78. Family TROGLODYTIDÆ. The Wrens.

338 (718). **Thryothorus ludovicianus** (Latham). Carolina wren.

Rare summer resident. On March 22, 1890, L. A. Fuertes found a pair on the west shore of the lake about four miles north of Ithaca where they bred that summer. It was not seen again until June 12, 1903, when a pair was found in Cascadilla gorge on the Cornell campus where they remained until observations ceased about the middle of August.

339 (721). **Troglodytes aëdon** Vieillot. House wren.

Common summer resident. The average date of arrival is April 30, the earliest, April 26, 1905 and 1906. Eggs are found from May 25 to July 10. They are much reduced in numbers by the middle of September and all have left by the last of the month. In the southern portion of the basin this species has increased seventy-five percent in the last 10 years.

340 (722). **Nannus hiemalis** (Vieillot). Winter wren.

Common transient and regular but not common winter resident. Migrants arrive in the spring the very last of March or the first of April and are common until May 1. The latest date is May 7, 1907. It is quite probable that a few breed in the colder gorges, for on June 21, 1878, Mr. F. H. King[30] found five individuals in the Enfield Gorge just below the falls. One specimen was shot and proved to be "a fully fledged young bird, but so immature as to leave no doubt that it was one of a brood which had been reared in the glen." They make their appearance in the fall about September 25.

341 (724). **Cistothorus stellaris** (Lichtenstein). Short-billed marsh wren.

One specimen, taken October 15, 1898, by T. L. Hankinson in the Renwick marshes.

342 (725). **Telmatodytes palustris** (Wilson). Long-billed marsh wren.

Common summer resident. The average date of arrival is May 2, the earliest, April 18, 1906. It has been recorded (seen) twice in winter—1904 and 1905. Eggs are found from May 20 to June 15 and occasionally as late as the middle of July. It remains in the fall until the last of October.

79. Family CERTHIIDÆ. The Creepers.

343 (726). **Certhia familiaris americana** (Bonaparte). Brown creeper.

Common transient and winter resident. They become abundant in the spring about March 20 and continue so throughout April. All have left as a rule by May 10 at which time they are frequently in full song. They arrive in the fall about September 15 and are abundant from October 1 to 15.

80. Family SITTIDÆ. The Nuthatches.

344 (727). **Sitta carolinensis** Latham. White-bellied nuthatch.

Common permanent resident. Eggs are found from April 19 to May 10.

[30] *Bulletin of the Nuttall Ornithological Club,* Vol. III., p. 195.

345 (728). **Sitta canadensis** Linnæus. Red-breasted nuthatch.

Common transient and occasionally found in winter. The average date of spring arrival is May 5, the earliest, April 28, 1908. None have been recorded later than May 30. On January 5, 1908, a specimen was shot at Ithaca and January 31 another was seen. A second specimen was taken at Ithaca, January 25, 1909. The first migrants arrive from the north the very last of August, becoming common the first two weeks in September. They remain until the middle of November.

81. Family PARIDÆ. The Chickadees.

345*a* (731). **Baeolophus bicolor** (Linnæus). Tufted titmouse.

An adult male was taken May 30, 1909, at Michigan Hollow.

346 (735). **Penthestes atricapillus** (Linnæus). Chickadee.

Common permanent resident. Nests with eggs have been found from April 29 to June 3. The earliest record of nest-building is March 24, 1890.

82. Family SYLVIIDÆ. The Old World Warblers.

347 (748). **Regulus satrapa** Lichtenstein. Golden-crowned kinglet.

Common transient and an occasional winter resident. The average date of spring arrival is April 1, the earliest, March 13, 1903. The average date of departure is May 7, the latest May 17, 1902. Migrants arrive in the fall as early as September 8, but they do not become common until the first of October. They remain until November 10.

348 (746). **Regulus calendula** (Linnæus). Ruby-crowned kinglet.

Common transient. The average date of arrival is April 19, the earliest, April 12, 1907. The average date of departure is May 9, the latest, May 22, 1907. In the fall the first arrivals are noted the last of September. They are common from October 1 to 15 and have disappeared by the twenty-fifth of the month.

83. Family TURDIDÆ. The Thrushes.

349 (755). **Hylocichla mustelina** (Gmelin). Wood thrush.

Common summer resident. The average date of arrival is May

8, the earliest, May 2, 1908. The breeding season lasts from May 25 to June 20. The latest fall date is November 6, 1908.

350 (756). **Hylocichla fuscescens** (Stephens). Veery.

Common summer resident. The average date of arrival is May 3, the earliest, April 24, 1908. Eggs have been found from May 19 to June 21, but the maximum breeding period is from the first to the middle of June. The majority of individuals have left for the south before September 20. The latest fall date is October 16, 1901.

351 (757). **Hylocichla aliciæ** (Baird). Gray-cheeked thrush.

Numerous specimens of this thrush have been taken in the basin but they are not scattered enough and field observations are not certain enough to justify limiting dates. We believe, however, that it is not an uncommon transient.

352 (758*a*). **Hylocichla ustulata swainsoni** (Cabanis). Olive-backed thrush.

Common transient. The average date of arrival is May 5, the earliest, April 21, 1900. It is not common after May 25 but has been seen as late as June 8. Migrants begin to arrive from the north about September 5 and are common from September 20 to 30. The latest fall date is October 21, 1908. Mr. L. A. Fuertes found a pair breeding in the Fall Creek gorge in the summer of 1890.

353 (759*b*). **Hylocichla guttata pallasii** (Cabanis). Hermit thrush.

Common transient. The average date of arrival is April 13, the earliest, April 1, 1908. The migration ceases about May 20. It breeds in small numbers on Snyder and Turkey Hills. It is common through October and usually departs before November 1. The latest date is October 31, 1905.

354 (761). **Planesticus migratorius** (Linnæus). Robin.

Common summer resident and present regularly in small numbers in winter. The first migrants arrive about the middle of March from which time this species is common until November 20. The breeding period extends from the first of April to the middle of July.

355 (765*a*). **Saxicola œnanthe leucorhoa** (Gmelin). Wheatear.

A young female was taken in the town of Junius, Seneca Co., September 9, 1872, by C. J. Hampton. The specimen is now in the collection of E. H. Eaton.

356 (766). **Sialia sialis** (Linnæus). Bluebird.

Common summer resident. The average date of spring arrival is March 9, the earliest, February 24, 1906. It is abundant through the larger part of October. Usually by the first of November all have departed. Eggs are found from March 30 to June 1.

F. Class MAMMALIA.

XXXVIII. Order MARSUPIALIA. The Pouched Animals.

84. Family Didelphididæ. The Opossums.

357. **Didelphis virginiana** Kerr. The Virginia opossum.

The opossum has been captured in the vicinity of Ithaca at various times since 1860. F. C. Hill has mentioned[81] the escape of a female and twelve young from Dr. B. G. Wilder's laboratory at Ithaca about 1878. There are no museum records of this escape and Dr. Wilder has no recollection of such. In the summer of 1896 seven individuals escaped from a cage in the Renwick Park where they were on exhibition. During the following six or seven years numerous specimens were captured about Ithaca, while prior to that time none had been seen for a number of years. The latest record is a male captured in the fall of 1903. Dr. Wilder's notes record specimens taken in 1860 and 1872 long before any individuals were known to have escaped from captivity.

XXXIX. Order GLIRES. The Rodents.

85. Family Sciuridæ. The Squirrels.

358. **Sciurus hudsonicus loquax** Bangs. Southern red squirrel.

This species is by far our most common diurnal mammal. It is not confined to any particular habitat, being found alike in all

[81] Hill, F. C., "The Opossum at Elmira, N. Y.," *Am. Nat.*, Vol. 16, 1882, p. 403.

kinds of localities. There is but one record of a pure albino but individuals with albinistic tendencies are not infrequent. The young are born the last of March or the first of April.

359. **Sciurus carolinensis leucotis** (Gapper). Northern gray squirrel.

Fairly common throughout the basin. It is believed by many that this species is no longer found in the southern portion of the basin. On Cornell Heights, along Fall Creek, along the Buttermilk gorge, in the region of Enfield gorge and on the tops of all the hills they are still common. The black phase is rarely seen although it is stated that such individuals were relatively very common. Two albinos have been taken at Danby.

360. **Sciurus ludovicianus ludovicianus** Bangs. Northeastern fox squirrel (introduced).

In the spring of 1906 six pairs were brought from another locality and liberated in a small grove of oaks on the Cornell Campus. During the first two months after their liberation several were found dead and brought to the laboratory. Each showed signs of bruises underneath the skin and it was thought that boys and slingshots were responsible. They had been reared in captivity and were extremely tame. Mr. A. A. Allen who looked into this matter informs us that they were very clumsy, probably due to confinement, and died from injuries received in falling from the trees. One individual which fell from a considerable height was dead before the spot where he had fallen was reached. During the fall of 1906 a few of the survivors remained in the oaks on the campus where they constructed large nests of leaves but apparently none successfully passed the winter. A few migrated to the woods along Cascadilla Creek where they did survive the winter of 1907–8 and one pair at least reared young during the following spring.

361. **Tamias striatus lysteri** (Richardson). Northeastern chipmunk.

Abundant, especially along the ravines, stone fences and in old wood lots. It is not found in the marshy areas. It goes into winter quarters during the latter part of November and remains until the middle of March. The latest fall record is November 26, 1906. The earliest it has been seen in spring is February 26, 1905. Mr.

A. A. Allen informs us that the young are brought forth a little later probably than with the other squirrels, for on May 9, 1908, a female was secured which showed signs of recent suckling.

362. **Marmotta monax** (Linnæus). Woodchuck.

Abundant throughout the basin in the more open and dry areas. It goes into hibernation about the middle of November and is not found abroad again until the first part of March, usually before the first snows are melted. An adult male albino was taken during the spring of 1876. On April 13, 1901, T. L. Hankinson shot a female which contained three fetuses (one in the right and two in the left horn of the uterus) 50 mm. in length.

363. **Sciuropterus volans volans** Bangs. Southern flying squirrel.

Common throughout the basin wherever suitable hollows for nests or cover during the day are obtainable. The young are born about the middle of April.

86. Family Muridæ. The Rats and Mice.

364. **Mus musculus** Linnæus. House mouse.

Abundant in buildings, open fields and woods in the lowlands about the head of the lake.

365. **Mus norvegicus** Erxleben. Norway rat.

Abundant. Found in the same abodes and areas as the preceding species. During the winters of 1907–8 and 1908–9 there were three instances of persons attacked while sleeping by individuals of this species.

366. **Peromyscus leucopus noveboracensis** (Fischer). Deer mouse.

Common throughout the basin. Breeding begins April 15 and continues until August. Mr. A. A. Allen observes: "Three to five young about once a month for five or six months of the year, serves to preserve the species."

367. **Peromyscus maniculatus gracilis** (Le Conte). Canadian white-footed mouse.

This species is common on Turkey Hill and in Michigan Hollow. It will undoubtedly be found on some of the other high hills when search is made.

368. **Fiber zibethicus** (Linnæus). Muskrat.

Common along water courses and in the marshes.

369. **Microtus pinetorum scalopsoides** (Audubon and Bachman). Northern pine mouse.

On September 18, 1898, T. L. Hankinson took a specimen in a small evergreen woodland about two miles east of Ithaca. On March 14, 1909, another specimen was taken by A. C. Chandler on Snyder Hill.

370. **Microtus pennsylvanicus** (Ord). Common eastern field mouse.

Common. It is found to be the most abundant rodent in the moist lowlands.

371. **Evotomys gapperi** (Vigors). Eastern red-backed mouse.

Common in all the higher wooded regions, in the sphagnum bogs near McLean and the marshy land in Michigan Hollow.

87. Family Dipodidæ. The Jumping Mice.

372. **Zapus hudsonius** (Zimmerman). Northern meadow jumping mouse.

Common in the moist lowlands. It begins to hibernate in late November and emerges about the middle of April.

372*a*. **Napæozapus insignis** Miller. Woodland jumping mouse.

One specimen (5207), a female, was taken in Michigan Hollow, June 14, 1909, by Messrs. A. A. Allen, F. Harper and J. S. Gutsell.

88. Family Leporidæ. The Hares.

373. **Lepus americanus virginianus** (Harlan). Southern varying hare.

This species has disappeared from many localities in the basin. It is still fairly common in the vicinity of Connecticut Hill, in the hills near Danby and Caroline and the series of hills about Dryden. The summer pelage begins to show in the latter part of March.

374. **Sylvilagus floridanus mearnsi** (Allen). Eastern prairie cottontail.

Common in wooded, open, dry and marshy lands alike. All the

specimens taken in the basin have been identified by Dr. E. W. Nelson, of Washington, who writes:

> There is remarkably wide variation in the skulls of this lot though the specimens are externally so much alike. Ithaca is on the border line between the ranges of two subspecies and while these specimens are intermediate in some characters they are not very close to either subspecies (*mearnsi* and *mallurus*).

XXXX. Order FERÆ. The Flesh Eaters.

89. Family FELIDÆ. The Cats.

375. **Lynx canadensis** Kerr. Canada lynx.

A female now in the collection of Cornell University (C. U. 4834) was killed north of Wilseyville N. Y., November 16, 1906. Another was seen in the same locality a few days later. During the latter part of October, 1908, another specimen was shot near Park Station, about ten miles west of Spencer. It is now in the possession of John C. Munson of Erin, N. Y.

90. Family CANIDÆ. The Dogs.

376. **Vulpes fulvus** (Desmarest). Red fox.

Common and in some localities gradually increasing in numbers. They are especially abundant in the vicinity of Newfield and Danby. The young are born about the first of May.

91. Family MUSTELIDÆ. The Weasels.

377. **Lutra canadensis** (Schreber). Otter.

While formerly quite common it is probably no longer to be found in the basin. The last specimen noted was an adult male taken in the gorge at Enfield, April 27, 1894.

378. **Putorius vison vison** (Schreber). Southeastern mink.

Common in the swamps and along water courses. They are still a source of considerable returns to the trappers.

379. **Putorius cicognanii** (Bonaparte). Small brown weasel.

Common in woods, fields along fences and water courses.

380. **Putorius noveboracensis** Emmons. New York weasel.

Abundant. Found in woods, stone piles, brush piles, stump fences and places of the like. The change from summer to winter

coat is completed the last of November and by the first of May the summer coat is again complete.

381. **Mephitis putida** Boitard. Southeastern skunk.
Abundant in all localities.

92. Family Procyonidæ. The Raccoons.

382. **Procyon lotor** (Linnæus). Raccoon.
Common throughout the basin.

XXXXI. Order INSECTIVORA. The Insect Eaters.

93. Family Talpidæ. The Moles.

383. **Condylura cristata** (Linnæus). Star-nosed mole.
Common in swampy and moist ground.

384. **Scalops aquaticus** (Linnæus). Naked-tailed mole.
Two specimens were taken at Taughannock Falls in 1907.

385. **Parascalops breweri** (Bachman). Hairy-tailed mole.
One specimen taken near North Spencer by T. L. Hankinson, June 9, 1902.

94. Family Soricidæ. The Shrews.

386. **Blarina brevicauda** (Say). Short-tailed shrew.
Abundant throughout the basin and taken at all times of year.

387. **Sorex fumeus** Miller. Smoky shrew.
Fairly common in the higher hills and upland marshes.

388. **Sorex personatus** Geoffory St. Hillaire. Long-tailed shrew.
It has been found only in the swamps near Danby and in Michigan Hollow where it is common.

95. Family Vespertilionidæ. The Ordinary Bats.

389. **Lasiurus cinereus** (Beauvois). Hoary bat.
From data collected during the past few years by Mr. A. A. Allen it appears that this species visits the lake basin during the fall migration only. Although diligent search has been made no specimens have ever been taken except in the month of October. Data

collected outside the basin indicate that its occurrence here is limited to the fall.

390. **Lasiurus borealis** (Müller). Red bat.

One of the most abundant bats of the region. In the spring they are not much in evidence until the middle of May and disappear the last of October.

391. **Lasionycteris noctivagans** (Le Conte). Silvery-haired bat.

Common, especially in the gorges. It appears the first of May, the migration reaching its height by the middle of the month.

392. **Pipistrellus subflavus** (F. Cuvier). Pipistrelle.

Common, especially in the gorges. It appears in the spring the first of May along with the silvery-haired bat and is the last of all our bats to disappear in the fall. Specimens have been taken as late as November 1.

393. **Vespertilio fuscus** Beauvois. Big brown bat.

Common. It is the first bat to appear in the spring. It may be looked for the first of April a month before any of the others are seen.

394. **Myotis subulatus** (Say). Say's bat.

One specimen taken at Ithaca, July 2, 1904, by A. G. Hammar.

395. **Myotis lucifugus** (Le Conte). Little brown bat.

This is the most common bat of the region. They appear in the spring the last of April.

FURTHER NOTES ON CEREMONIAL STONES, AUSTRALIA

By R. H. MATHEWS.

(Read October 1, 1909.)

During the latter part of 1908 I submitted an article on the above subject, accompanied by diagrammatic drawings showing front and side views of several specimens.[1] Since that time I have obtained a photograph of a number of similar stones in the possession of Mr. A. G. Johnston, of Murtie Station, Darling River, New South Wales. I have thought that the publication of this photograph will add to the value of what has already been written and encourage further investigation in this important subject.

In explanation of the photograph, Fig. 1, the specimens are contained in a cabinet in which there are three shelves. I have ruled lines across the face of the photograph corresponding to the bases of these shelves, the picture being thus divided into three partitions, marked *A, B* and *C,* for the purpose of explaining its contents.

Partition *A,* or the lower shelf, contains thirty-two ceremonial stones, of various lengths and proportions, which the reader will readily recognize from a perusal of the drawings in my former article on the subject. The four large flat, ovate stones at the back of the shelf, are lower millstones, used for grinding grass seed. There are also three upper millstones, which are much smaller, used for pounding and grinding the seed upon the larger lower stone. The upper millstones, as well as four stone hatchets, are not distinguishable without the aid of numerals. I have not thought it advisable to number any of the objects, lest the picture should be overcrowded and defaced. In the middle of the shelf, near the top, is a boomerang.

Partition *B,* or the middle shelf, has fourteen more ceremonial stones, four lower millstones, one upper millstone, four stone

[1] Proc. Amer. Phil. Soc., Vol. XLVIII., p. 313.

hatchets, a boomerang, a nulla-nulla, and a kopai ball like those illustrated in my paper on "Burial Customs."

Partitition *C*, or the uppermost shelf, contains four more ceremonial stones, two lower millstones, four stone hatchets, and a black-

FIG. 1. Ceremonial stones, nardoo stones, boomerangs and nullas.

fellow's skull. It appears therefore, that the cabinet, with its three shelves, contains a total of fifty ceremonial stones, without counting the other specimens. Owing to the great number of articles comprised in Fig. 1, everything appears proportionately small. To remedy this, several representative specimens of ceremonial stones have been taken out of the cabinet and a separate picture, Fig. 2, photographed on a larger scale. Nos. 1, 2, 3 and 4 are reddish

tinted sandstone, all of them being more or less profusely ornamented with incisions. Nos. 5, 6, 7 and 9 are gray sandstone.

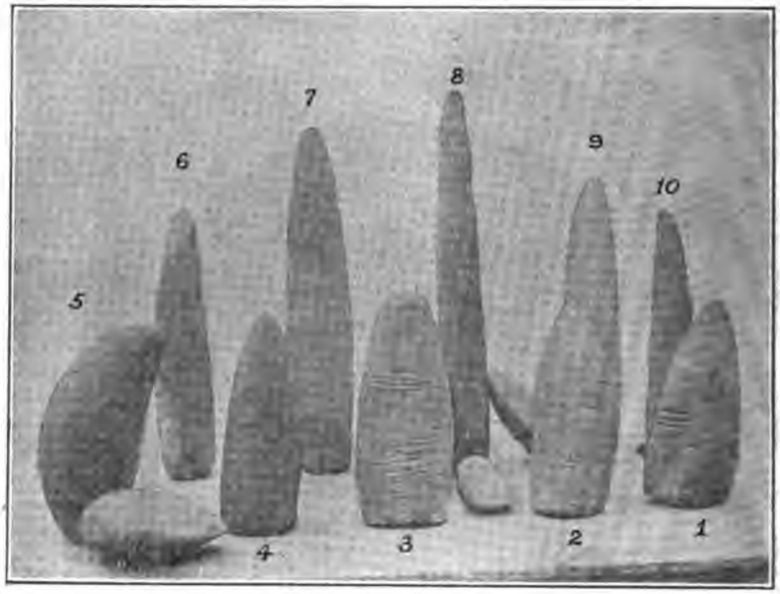


FIG. 2. Ceremonial stones. Nos. 1, 2, 3, and 4 are of red sandstone, all much marked. Nos. 8 and 10 are of slate. No. 8, is 19 inches long. The rest are of gray sandstone.

Nos. 8 and 10 are clay slate—the former being nineteen inches long. The three small articles on the floor of the picture are stone hatchets, and are without numbers.

The two plates now submitted, if studied in connection with the comprehensive diagrammatic drawings given in my former article, will enable the reader to form a very clear conception of what these remarkable stones look like.

Joseph Wharton

COMMEMORATIVE ADDRESSES

AND OBITUARY NOTICES OF MEMBERS DECEASED

Ch. Darwin

From Etching by Leopold Joseph Flameng of Painting by Hon. John Collier

COMMEMORATION

OF THE

CENTENARY OF CHARLES DARWIN'S BIRTH

(FEBRUARY 12, 1809)

50th AND THE

FIFTEENTH ANNIVERSARY OF THE PUBLICATION

OF THE

"ORIGIN OF SPECIES"

(NOVEMBER 24, 1859)

PERSONAL REMINISCENCES OF CHARLES DARWIN AND OF THE RECEPTION OF THE "ORIGIN OF SPECIES."

BY HIS EXCELLENCY, THE RIGHT HONORABLE JAMES BRYCE.

(Read April 23, 1909.)

I count it a great honor to be invited to attend this meeting of the Society on this celebration of a very great man, who is one of the glories of our common race, and whom it is fitting that all members—not only the members of that common race, but all who belong to the great republic of science and letters, should join in commemorating. There is nothing more inspiriting to those who are citizens of that republic than the thought that one belongs to a universal company, embracing not only all nations and tongues, but all ages and countries, which is engaged in the same common pursuit of endeavoring to discover truth and to advance the bounds of knowledge. I feel it a particular honor to be asked to join to-night in celebrating one of the brightest luminaries of modern science, of whom we English are proud, and on no occasion has the function of representing my country in your country been more prized by me than when it gives me the opportunity of coming here to join in this celebration as representing, however unworthily, British men of letters and the oldest of British scientific societies.

Ladies and gentlemen, a few words may be said upon some of the general aspects of this subject, which will be dealt with more completely by the third of the speakers who is to address you to-night.

When I was first invited to attend the meeting I was asked to say something regarding the influence of the Darwinian theory, and in particular to what is called the Doctrine of Evolution upon history and the political and economic sciences. I felt obliged to decline so great a task as that, partly because it required a wider knowledge than I possess, and partly also because I have never been able to feel sure that the influence—that is to say, the direct influence—of the doctrines contained in Mr. Darwin's writings upon the historical and political sciences is so great as has sometimes been supposed. Upon this subject my mind is quite open, and I shall be very glad to be convinced by the third of the speakers, that it is greater than I have been hitherto led to believe, but it seems proper to say a few words to you on the subject in order to state the views which some at least of the students of history hold and to invite an answer to them from the subsequent speakers.

Now, there is no doubt at all about this, that great changes have passed within the last two generations upon the study of historical, political and economic science. That, I suppose, we are all agreed upon. They are studied more scientifically; that is to say, they are studied with more exactitude and more precision than formerly. But it may be doubted whether this change in the method of studying historical and economic science is due to the influence of the physical sciences. If you examine the matter chronologically, it will appear that instead of being due to the recent growth of those sciences, it is due to causes which produced the rapid contemporaneous advance of the sciences of nature as well as the progress of historical and economic science. In other words, the more exact character of the human sciences has had an independent origin and source.

Let me say in passing that the influence upon history of some writers, who have dealt both with natural science and with history and tried to handle both subjects together, attempting a sort of synthesis, appears to me to have been greatly exaggerated. It is,

to say the least of it, very doubtful whether Auguste Comte, for whom so much is claimed by his disciples, really made any substantial addition to historical science. There is little, if any, ground for thinking—I have certainly never seen any evidence to show—that either Mr. Herbert Spencer or Mr. Buckle has brought any contribution of substantial value to either historical and political or to economic science. Indeed, as regards these two last named writers, most historians would say that it is hardly possible that they could have made any contribution to the knowledge of history as a science, because when they came to the details of history, they showed themselves quite uncritical—they were not accustomed to weigh evidence, or to test it by historical standards, and the general ideas which they put forward are old ideas, which were perfectly familiar to competent historians before either of them touched the pen. The case, however, with regard to the great thinkers in the field of natural history, and particularly as regards Charles Darwin, is a different case. We all admit and gratefully recognize the immense general intellectual stimulus which the writings of Mr. Darwin gave to everybody who was working in any field of enquiry by scientific methods. He stimulated all serious students, whatever their subject was, because his researches opened up fields new to many historians, and he pursued his enquiries—I will not say by new methods, but with a greater perfection and finish of method and with a more suggestive fertility of mind than perhaps had been done before. His books were read and pondered on by not a few men of letters, who had previously known very little of science. In that way, therefore, the effect of Darwin's writings was very great indeed. Moreover, he gave an example of careful and patient observation, of scrupulous detachment, of exquisite candor and fairness of mind in the process of investigation, which told very greatly on everyone who followed his researches and reflected on his conclusions.

Coming particularly to what is called the doctrine of Evolution, let it be at once admitted that in the branch of history that belongs to primitive man, that considers the growth of our race in its very earliest stages, and the development of his moral ideas and social habits, some of Mr. Darwin's suggestions were striking and illumina-

tive. But the specific doctrine of evolution, as applied to history, is not a new thing. In history it is a very old thing. All thoughtful and penetrating historians have always seen and recognized that there was constant progress and growth in human affairs, not necessarily permanent and perpetual progress, but at any rate change. They have recognized that there has been a process of flux and a ceaseless development always going on through human society. The process of change in ideas takes place by the action of what may be called the critical spirit—that is to say, the meaning and the effect, the scope and the limitations of all our ideas and all our conceptions are constantly being played upon by an analytic and speculative mind. The whole mind of the community—that is to say, all the thinking part of the community—is incessantly dealing with the conceptions and ideas which it has received from its predecessors, and these are thus being always imperceptibly altered under the influence of this examination and of the speculation which accompanies it, so that each succeeding generation hands on to the next something different from what it had received. That is what "evolution" substantially means in the sphere of philosophical thought, and that has long been practically recognized and understood. The process has in it something which is analogous to the process by which change and differentiation go on in the animal and vegetable kingdoms. But it is not the same thing, and instead of requiring the long and careful observation which modern naturalists have applied to determine how it goes on in the animal and vegetable kingdoms, it was a thing that was in a certain sense so obvious that great historians have perceived it from comparatively early times. For instance, the development of the civilized races of mankind out of a very low and brutish state had been recognized as far back as the philosophers of Greece. You remember the familiar lines of Horace

> Cum prorepserunt primis animalia terris
> Mutum et turpe pecus.

And in the sphere of institutions, historians and political thinkers have always recognized that man is largely the creation of the conditions that surround him, and is profoundly influenced by them. They have always seen that institutions grow through being de-

veloped by the gradual and constant process of experiment succeeding experiment, and reaction followed by reaction. Institutions are the result of many efforts after improvement made sometimes consciously and sometimes unconsciously. If an experiment succeeds, it is developed further. If it fails, it is dropped and another takes its place. If you look at the Roman Constitution, or at the English Constitution, you will see that either in its mature form represents a regular process of development by a constant series of small changes. That is in the historical sphere, what we mean by evolution. So it has always been known that the stronger races survive and weaker races perish; that efficient institutions—that is to say, such as are fitted to stand the strain of strife—maintain themselves in the struggle for life, while other and weaker institutions, which do not so well hold men together, and give strength and vigor and vitality to the body politic, disappear. This is one of the lessons of history, and a lesson which men could not but begin to read pretty early. Accordingly the doctrine of evolution in that sense was a doctrine long ago understood, if not always fully and explicitly set forth by historians, and the scientific spirit in historical science seems to be not the daughter of the same spirit in natural science, but the sister, beginning to show itself about the same time. You can fix that roughly at not less than one hundred and fifty years ago, in the first half of the eighteenth century. In the end of the seventeenth century when the Royal Society was founded and more markedly in the eighteenth century the world began to have a critical and analytical spirit, and it spread in all directions and to all subjects. This spirit was already alive and working among the votaries of the historical and modern sciences. It was known to Bentley. Such a book as Wolf's "Prolegomena" to the Iliad is a remarkable example of it. It had begun to be applied to the early Hebrew writings. One finds it in Adam Smith and in Gibbon. Niebuhr was not the first to be inspired by it in dealing with Roman history. This was happening at the very same time, when it was at work in such sciences as physics, chemistry and geology in the days of Black and of Priestley and of Lavoisier and of Hutton, and, let us never forget, when it was exemplified

and applied by the illustrious founder of this Society, Benjamin Franklin.

From this comparison of the growth of this scientific spirit in these two branches, the human sciences, and the sciences of observation in the natural world, such as physics and chemistry and natural history, let us return to note the great effect which during the last eighty years the growth and rapid advance of natural science in all its branches has exerted upon the students of historical and political sciences. To-day natural science, to a degree which was never known before, has come to permeate the atmosphere that we breathe. It is impossible for anyone who has any tincture of letters or knowledge not to feel that he is moving about in a world permeated by ideas and methods of natural science to the extent that was never known at an earlier period of history. This has, of course, told upon the students of historical and political science. It has made them endeavor to emulate that attention to the smallest details, that accuracy in observing and recording, which the votaries of natural science bring to their work. We are all debtors to the men of science for helping to impress these things upon us and for giving us the highest standard of diligence, of patience, of care, of the removal of all personal emotion and feeling from the quest of truth. In this way there can be no doubt at all that the natural sciences have had a potent influence upon the growth of the sister sciences which deal with human affairs. It would indeed be a good thing if everyone who studied history and those other sciences were to acquire some knowledge—at least an elementary knowledge, and elementary knowledge need not be a superficial knowledge—of the methods of some one of the natural sciences, because it would tend to raise his conception of what the exactitude and finish of scientific method may be, and improve him in applying it to his own line of research. Every serious student, whatever his special subject, must be grateful to Charles Darwin for the light he cast on the field of natural knowledge. He enlarged our conception of the reign of law through the whole realm of animate nature, and he also presented in his own person a shining ensample of the mental and moral qualities and habits which every man ought to bring with him into the search for truth. In these respects we who follow the study of history honor

him, a little further off than you votaries of the natural sciences do, but not less sincerely and not less reverentially.

Now, ladies and gentlemen, I am asked to say a few words to you about the effect which was produced by Mr. Darwin's writings when they first appeared in England. I am, unfortunately, old enough to be able to remember that time: and one of the few compensations that one finds in advancing years is the opportunity to call upon for the benefit of friends recollections which are still fresh of days now so far past that they are becoming matters of written history. The effect of the "Origin of Species" was extraordinary. There has been no such effect before or since, in the way it stirred men's minds in England. I recollect that in or about the year 1853 the British Association for the Advancement of Science held its annual meeting in Glasgow, and I was taken by my father, who was himself a scientific man, to attend that meeting. I was only a boy of fifteen, but he, very properly, thought that you cannot begin too soon to endeavor to bring the youthful mind into contact with science and men of science, and, accordingly, he took me to attend the meetings of the Association. I remember that at an evening meeting there was delivered a lecture, supposed to be of a comparatively popular kind, intended to bring scientific conceptions to the minds of those members of the association who were interested in science, but not skilled scientific students. The lecture was upon Species, and it was delivered by Dr. William B. Carpenter, who was a well-known and much respected scientific writer in that time, careful and thoughtful, though not a discoverer. The lecturer and the audience and the impression come back to me as if it was yesterday. He brought out with great fulness and clearness all the difficulties that attach to every hypothesis about the origin of species. He stated the old familiar doctrine of separate creation, and showed the objections to it. He threw out various conjectures upon the subject, and explained the objections that attached to each one of the various hypotheses advanced. And he left us as much in the dark as we were before. This was startling to a youthful and ingenuous mind, who had expected to be told what to think. We who were not in the inner scientific circles said to ourselves "Why in the world is this lecture given to us, if we are, after all, to be left with no positive

conclusion which we may carry away? There must be some problem more perplexing than we knew of." But in meditating upon the matter one perceived that the scientific world had been slowly moving up to the threshold, and was pausing at the threshold, of some great discovery. Some solution must be at hand, but nobody knew—nobody at least, outside of a very small circle—how near the solution was or what it was going to be. We left the lecture room, excited, perplexed, recognizing difficulties that we had never known of before, and wondering what the outcome was going to be. Five or six years later the "Origin of Species" appeared, and the impression which it produced was enormous. No book dealing with a scientific subject had ever, I suppose, been so largely read by people who were not scientific. I was an undergraduate at Oxford at the time, and I recollect very well that many of my fellow undergraduates who never opened—I will not say a scientific, but hardly even a serious book before—procured the treatise and read it with avidity. We all talked about it. We discussed it with the greatest ardor, indeed, with a positiveness which was in inverse ratio to our knowledge; and it was the same all over England. "The Origin" was not only the subject of constant comment in magazines and newspapers as well as at meetings of scientific societies, but it furnished a theme for constant jests in the comic papers, and it was an unfailing topic for conversation in all cultivated private houses. There was, of course, a good deal of alarm created by it. The alarm was perhaps not quite as great as some people have since represented. In England we had long been occupied by what was called the "conflict between theology and geology," so the new doctrine in its bearings on the Scriptural account of the creation did not find us altogether unprepared. There had been a good many scientific geologists, who were also religious men, some, like Dean Buckland and dear old Professor Sedgwick, of Cambridge, some of them clergymen, and who had continually said there could not be any conflict between science and religion. But still, apart from the more educated persons and those whom they influenced, there was in many circles, particularly, of course, in the ecclesiastical circles, a good deal of alarm and a great deal of somewhat heated discussion. Some hard words were said even about Mr. Darwin himself.

To those he never replied. He showed the greatest dignity and the greatest wisdom, never descending into the arena. But he soon found champions, and among others he found one, who then first came into notice and then first showed his remarkable controversial powers, powers which he was fond of displaying—and indeed could not help displaying, because when a man has a gift he cannot help enjoying the use of it—I mean the late Professor Huxley. Huxley was then a comparatively young man. He embraced Mr. Darwin's doctrines with great eagerness, and he championed him with passionate zeal. I recollect a little incident that happened about that time, which may possibly be worth recalling to your memory. There was a meeting of the British Association held not long after the "Origin of Species" had appeared—I think within two or three years—at which the then Bishop of Oxford, Dr. Samuel Wilberforce, was brought down as an ecclesiastical champion to demolish Darwin. He was a man of remarkable oratorical powers, with a quick, ready and flexible mind, acute and witty, and able, like a practiced rhetorician, to make the best of any case presented to him, with not much regard to the truth of the facts or the soundness of the argument. There occurred a controversy between him and Mr. Huxley at one of those meetings. The bishop had made a clever and amusing speech, in which he showed up what he conceived to be the weak points of the Darwinian theory, and turned it, as far as he could, into ridicule —asking the audience, with some scorn, whether they wished to be descendants from apes, whether that was the kind of ancestors they could look back to with pride, and sat down amid a tempest of applause, after having, as his supporters thought, succeeded in making the Darwinian theory not only improbable, but even contemptible. Mr. Huxley rose to reply, and after setting forth with great force and ample knowledge his serious argument, observed that the Bishop of Oxford had asked whether any man there would like to have an ape for his ancestor. For his part, he would say only this, that if he were obliged to choose between having for his ancestor an ape, or having for his ancestor a man who, enjoying a high position and a great reputation, being possessed of brilliant oratorical powers and a fund of sarcastic wit, were to use that position and those powers for the sake of obstructing the progress

of truth, and trying to pour ridicule and scorn upon those who were humbly and patiently trying to discover truth, then, he proceeded, "If I were compelled to make that choice, I would—." At this he stopped and said, "But perhaps I better go no further."

These personalities, however, so far as Mr. Darwin was concerned, soon died down. In the year 1870 he was offered an honorary degree by the University of Oxford, which was then a very much more clerical and conservative body than it is now, and the offer was made at the suggestion of Lord Salisbury, who was then Chancellor of the University, leader of the Conservative party in England, and himself a political champion of the Church of England. Everyone felt that the right thing had been done when the degree was offered, although, unfortunately, the weak state of Mr. Darwin's health prevented him from coming to receive it at Oxford. During the latter part of his life he was one of the most honored men in England. There was no one who did not respect and admire him, no one who did not consider it a privilege to have the opportunity of seeing him. He was, however, very seldom seen. Rarely has it happened that a man so famous should be so little personally known. His health had been weak for many years. He took up his residence at a hamlet called Down, in a hollow among the chalk hills of Kent, about fifteen or twenty miles southeast of London, quite a little remote place, three or four miles from the nearest railway station, with practically no neighbors, and there he lived, pursuing his researches, seldom receiving visits. I do not suppose he visited London once a year during the time he lived there. It was a happy, peaceful life that he led. He was surrounded by a devoted family, who took the greatest care of his health, and who helped him in his researches. He was singularly fortunate in his domestic relations and he had the unusual happiness for a scientific man of finding that nearly all his sons had scientific tastes, while one or two of them helped him effectively in the prosecution of his researches. Several of them have become eminent men or science. One was President of the British Association three years ago, and is a distinguished astronomer. Another one was President of the British Association last year and is a distinguished botanist. It was at his home that I saw him, a year and a half before his death.

One could converse with him for a few minutes only because his health was so feeble that it was necessary to save all the time he could spare for the prosecution of his work, as he was only able to work for two or three hours a day, perhaps even less, and talking fatigued him. The conversation I had with him lasted less than twenty-five minutes, and at the end of that time one of his sons came in and took him away to lie down and rest.

The portraits of him which you have seen are extremely good and give a correct impression of his features and air. I can hardly imagine a more faithful representation, both of the features and of the expression of his face than you have in the picture placed on the easel in this room.[1] He was one of those men whose character was palpably written on his face. He had a projecting brow, with a forehead very full over the eyes, and a fine dome-shaped head. His eyes were deep set, because the brow projected so far, and were of a clear and steady blue, and he had a quiet, contemplative look, with an occasional slight smile passing over his countenance which made one feel perfectly at ease in his company. There was nothing about him to make a stranger feel constrained or timorous in his company, however deep one's reverence, because his manner was simple, natural, with nothing to indicate any consciousness of distinction. As I knew two of his most illustrious contemporaries in the field of science, you may like to hear how their faces and that of Darwin struck an observer. One was Lord Kelvin, whom many of you here knew, and whom we lost only two years ago. He also had a striking face, but the thing that most impressed one was the activity, alertness and vivacity, the constant play of mind, the quickness and mobility of his expression. The other of these two great men was Helmholtz. He had a look of steadiness, concentration and solidity. His face was a kindly one, friendly and genial, but much quieter than Kelvin's. Helmholtz seemed to be continually bent upon thinking out some thought or calculation calmly and persistently. Mr. Darwin had the same tranquility, the same patience. His look was both penetrative and meditative. It was not so quick and capable of swift change as Kelvin's was, but it had nevertheless the keenness and sensitiveness of the man whom nothing escaped,

[1] Collier's portrait, etched by Flamang.

who saw everything that there was to see, whose eyes seemed to pierce beneath the surface of things. Acute observation and patient reflection were both written in it. One felt that hardly any problem would be too difficult to be solved by the steadiness and persistence of his thought.

As often happens, one cannot after the lapse of years remember much of the conversation that passed, and only a few things that Mr. Darwin said rise to my mind now. The subject of malaria and malarial diseases happened to be mentioned and their prevalence over large parts of the world. It was before the time of the discovery of the malaria-bearing mosquito, and he observed that if any one could discover a method of inoculation which would make men immune against malaria, that that would be one of the greatest discoveries of the world. He thought at that time that if this discovery came about it would be of supreme significance for commercial and political affairs by making possible the development by white men of large parts of the earth's surface, such as tropical Africa. He added it was a mistake to suppose that malaria was confined to marshy districts. In the Cape Verde Islands, which he had visited, when a heavy shower falls malaria appears within a day or two afterwards. The Cape Verde Islands are, he said, of dry volcanic rock, and yet in spots on them where there were no marsh at all heavy rains falling upon this volcanic rock would be quickly followed by an outbreak of malarial fever. Of course, we know now how to explain that, but he had been struck by the fact before others had discovered the part played by the mosquito.

The impression which his whole demeanour and conversation made was that of perfect candour and naturalness. There was nothing of what people call "self-consciousness."

Darwin left on every one who knew him the impression of a philosopher in that old sense of the word which makes it denote not only the love of wisdom and truth but the tranquility of mind, the calmness and peace, which devotion to truth brings. In him wisdom and the search for truth appeared to have had their perfect work, in forming a character, so beautiful in its earnestness, its modesty, its simplicity, its sweet serenity.

THE INFLUENCE OF DARWIN ON THE NATURAL SCIENCES.

By GEORGE LINCOLN GOODALE.

We are to examine the more striking features of a revolution which began half a century ago. The smoke and dust of controversy have drifted away, and it is now possible to see with some degree of clearness the magnitude of the issue and the nature of the reconstruction. In order to appreciate the completeness of the change, we must contrast, as fully as our time permits, the condition of the natural sciences fifty years ago with their state at the present time.

In 1858 Alfred Russell Wallace and Charles Darwin first gave to the public their fruitful suggestion in regard to the struggle for existence and the survival of the fittest. In the following year Darwin embodied this idea in his "Origin of Species," and illustrated it fully. Those two dates mark the beginning of a new era in natural science. By natural science, as distinguished from physical science on the one hand, and from mental and moral science on the other, is commonly meant that department of investigation which deals with living and extinct plants and animals, especially with regard to their structure and distribution. The century ending in 1859 was remarkable for its persistent attachment to a dogma in natural science which had proved more and more embarrassing as the century advanced. This dogma is known as that of the fixity, or permanence, of species.

The word species, denoting a particular kind of mineral, plant or animal, is very old in its general application, but it assumed in 1750 a definite meaning at the hands of a great reformer of natural history, Linnæus, of Sweden. He found the term used vaguely, and he gave to it a restricted signification. Everybody recognizes the fact that the living world around us is composed of individuals which resemble each other more or less closely. When these in-

dividuals resemble one another very closely indeed, just as parents and offspring are alike in almost all respects, they are held to constitute a species, varying within narrow limits, beyond which limits they never permanently trespass. This conception of species carries with it the notion that they have come down to us out of the past in straight lines of descent, or stating this in the words of Linnæus, there "are just as many species as there were forms created at the beginning." These fixed, permanent, created forms are species. As a matter of fact, in a few doubtful instances, Linnæus seems to have thought that a perplexing species might possibly have been derived from some variety of another species, but these questionable cases were so few that they cannot obscure the truth that Linnæus gave the whole weight of his authority in favor of the dogma of the permanence of species. Even in his lifetime there were bold speculators who ventured to express their skepticism regarding the validity of the dogma; but none of them made out a very good case against it, and eventually all serious opposition died away.

The influence exerted by Linnæus was largely due to his beneficent reforms in natural history, which placed the whole scientific world under obligation to him. Let us glance at these sources of his authority, by which his opinions in regard to species held almost undisputed supremacy for a full century.

Linnæus, at the beginning of his work, found a cumbersome and vexatious nomenclature. Certain sorts of plants had received names which were made up of more than twenty Latin adjectives trailing after a substantive. Linnæus cleared away this worse than useless nomenclature and replaced it by a binomial, or two-name system, which answered every purpose. Furthermore, he became so impatient at the tedious and prolix descriptions which filled many of the contemporary treatises on animals and plants, that he set himself to work to reform this fault. He constructed a sort of grammar of botany, known as philosophia botanica, in which he placed, in orderly manner, the rules which had governed him in framing his own descriptions. These rules met with general acceptance on account of their good sense, usefulness, and wide applicability. The rules insisted on brevity, clearness and accuracy. They have never been wholly superseded. Such were the two great reforms in

nomenclature and in description. They placed Linnæus in the position of a master whose word was law. Besides these two reforms which were promptly and gratefully accepted, there was also a suggestion made by him in regard to the identification of plants which was so useful and attractive that it greatly increased his influence. This suggestion led a host of amateur and professional explorers to seek new plants in all countries. Your own city shared in this, as Bartram's garden proves. Some of these plants were named and described by the explorers themselves under the rules of Linnæus, but a large proportion of the remainder were placed at the disposal of the great master. This convenient system of identification partook of the nature of a system of classification, thoroughly artificial, but eminently practical. Thus by his two immense reforms and by his ingenious system of classification, Linnæus reached a point where, consciously or unconsciously, he became a dictator in many departments of natural history. It must be remembered further, that his authority was greatly augmented by the wide range of his activities, for he lived and worked before the days of specialization. Hence he could give to the world a "Systema Naturæ."

In his reforms and in his provisional system he made use of two units, the individual and the species. The individual is the unit of description, the species is the unit of classification. Both of them presented curious difficulties of definition. Thus an individual is usually defined as a thing or an organism which cannot be separated into parts without losing its identity. But if we take an individual plant, say, of rose, we can divide it into a hundred different pieces, each of which is capable of independent growth. In the higher animals, like man, for instance, and in a great many of the lower plants, complete individuality is easily recognizable; but, on the other hand, many of the lower animals and practically all of our higher plants are communities rather than individuals. If any individuality at all exists, it is composite and corporate. The other unit, the species, fares hardly better at the hands of one who tries to define it strictly. If we take the definition already quoted from Linnæus or if we define it as "a perennial succession of individuals perpetuated by generation," the determination of any given case must be largely a matter of judgment, since, as a rule, the naturalist

does not and cannot have both parent and offspring to guide him in his decision. It often happens that only a single individual is at hand for description. This is especially the case in the study of collections made under difficulties, where it has been possible to get only one or two specimens of a kind. The judgment must control in such studies of resemblances. But inasmuch as we associate the idea of affinity with resemblance, the question kept arising in the minds of some naturalists even in the time of Linnæus, (if resemblance is the controlling factor in determining that two or more individuals, however variant, belong to a given species, and if we claim that a given species is a line of individuals related by descent, what are we to say when we find two species very closely resembling each other? Are they related also? And by descent? It is, in short, impossible to keep the idea of relationship by consanguinity out of the mind.) It forces itself at some time or other upon every student. Among those who were most embarrassed by this recurrent query which would not be silenced, was Buffon, the naturalist.

Strong [illegible] about the same

He appears to have been much troubled at different times by the perplexing question which could be explained only on the basis of transmutation, but he was not able to offer any suggestion as to the origination of species, which could be well defended. For a long time he sustained animated controversies with his contemporaries, but never to good advantage. Nor did Lamarck, another naturalist of about the same period, succeed in impressing upon his associates his views in regard to the mutability of species. He made suggestion after suggestion as to some possible method by which a change of conditions acting on the organism, could bring about a change of form and structure. He constructed a fabric of hypotheses by which he endeavored to account for the origin of species. But it is the concurrent testimony of all who have familiarized themselves with his work, that in the shape in which he urged it, it deserved a part of the ridicule with which it was ruled out of court. Geoffroy de St. Hilaire held similar views, but he could not convince his contemporaries that the suggestions were satisfactory. The poet Goethe also was intensely interested in the discussion, especially that which took place between St. Hilaire and Cuvier, and endeavored by his own writings to clear up many of

these matters. But none of these were able to make any headway against the authority of Linnæus and Cuvier. Time would fail us to enumerate the nature-philosophers as they were called, and the naturalists, who rebelled with little effect against the dominance of the dogma of the fixity of species.

Their rebellion was practically of no effect, and yet today we can see that they were right in many of their contentions. Professor Osborne has given us in his excellent work, entitled "From the Greeks to Darwin," a capital sketch of these views, tracing them down from early times.

The authority of Linnæus and of Cuvier was enough to offset any of the speculations on the other side. But when the century was far advanced, the need of the readjustment of views became increasingly evident. On the one hand was the obvious fact that species do not change enough from year to year, to account for derivative descent, but, on the other, there were many questions which could be answered only by frankly admitting such derivation. First of all, it was exceedingly difficult to meet the problems presented by fossil plants and animals. To face these problems, even in a half-hearted way, it was necessary to assume the occurrence of successive catastrophes and fresh creations. And when, especially by the work of Lyell, the geologist, it became plainer, day by day, that instead of sudden scene-shifting in the drama of animal and plant-life, the play had always gone with no interruption, the situation became almost desperate. Secondly, the existence of rudimentary organs could not be at all understood on the basis of fixity of species. Useless organs have no place whatever in that scheme of primary creation. Thirdly, there were hosts of questions arising in regard to distribution of plants and animals which no man could answer on the basis of constancy of species.

Meanwhile, collections were increasing, and problems were becoming more insistent. And so the century closed in 1858, with many dissatisfied naturalists throughout the world, who were still in the dark and without a guiding clue. There was not in any country any scientific explanation of these great questions which commanded confidence or even respect. The dogma of constancy of species bound fast with its fetters all natural science and hindered

further progress. It was at this time that Mr. Wallace and Mr. Darwin made their happy suggestion. The two communications were presented to the Linnean Society, on July 1, 1858, practically as a joint production. All the inflammable materials were at hand for a disgraceful contention as to priority between two path-breaking pioneers. Each one was confident that he had found a plan by which it was possible to cut one's way through a formidable tangle of phenomena. But these great souls, Darwin and Wallace, joint authors of the hypothesis, vied with each other to give the other full credit for independent discovery. And more than this, they searched for those who had thought out their thoughts before them, and were rejoiced when they found that at least one thinker had anticipated them both, and that very many thinkers had been near the discovery. This noble example of magnanimity must be placed among the factors which have created Darwin's immense influence.

The suggestion or hypothesis is chiefly a statement of admitted facts. Both of these naturalists had been overwhelmed by the luxuriance of life in the tropics and both had been readers of a treatise in which the relations of numbers of living beings to space and food had been intelligently treated. Surrounded by tropical plants, and investigating tropical animals, they independently applied the treatise they had been perusing to the conditions around them. Wallace and Darwin observed what everybody knows, that in countless cases, the offspring largely outnumber the parents, and that this necessarily brings about a struggle for space and food. They also were much impressed by the wide variability of species, some varieties turning slightly away from the parental type in one direction, and others in other directions. And thirdly they saw what every one sees, that the conditions surrounding the organism are undergoing changes in respect to light, heat, moisture and the presence of other organisms. And next, these two naturalists did what no one else (save one) had ever done, namely, they put these three factors together, and framed a suggestive hypothesis. The hypothesis merely places a suggestion under all the foregoing facts, and it is this—admitting, as everyone must, that there are more plants to be grown and more mouths to be fed than there is room or food for, is it not likely that the fittest among the varieties will, on the

whole, stand the best chance? Not necessarily the strongest, but those best fitted for the conditioning surroundings will survive. And then came a startling inquiry from both of them; may not all this perhaps account for much that we know about the structure and distribution of organisms and the groups of organisms which we call species? This is a very innocent question and the papers did not excite much attention at the time; in fact Mr. Darwin says that the only remark he could recall was by a naturalist who thought that all "that was new in them was false, and what was true was old."

A year later the same suggestion, amplified in many particulars and copiously illustrated was published in the famous work entitled the "Origin of Species," and then an alarm was sounded all along the line.

We pass now to a short study of the immediate effect of the publication of the "Origin of Species." Let us not waste any time in recalling the bitter strife which the alarm-signal began. Let bygones be bygones. Those who were most prominent in antagonizing the hypothesis are most anxious now to have their hostile attitude forgotten. In the first place, we may say in a general way that the hypothesis met every problem fairly and squarely. It explained the succession of life on our planet, and pointed out a solution of the most puzzling problems of distribution. There were a few questions in regard to fossils which seemed to demand that the hypothesis should be strengthened by one of the tentative hypotheses suggested by Lamarck, which had fallen into soil sterile in his time, but now receptive and fertile. It explained the mysteries of parasitism, and of vanishing and rudimentary organs. It opened up new fields of research in all directions, and gave a fresh interest to all the old parts of the science. It showed that resemblances meant relationship, that is, affinity by birth, and that it was no longer necessary to apologize shamefacedly for saying that two plants or two animals were related. Under the new light it could be seen that the species were no longer to be regarded as dry things to be placed on shelves and catalogued, but as histories to be wrought out. To be sure, this is not always easy to do, and there

are differences of opinion as to the affinities in certain cases. It is of course a matter of discriminating judgment.

The "Origin of Species" invaded at once new fields of research and stimulated investigation in all the territory around the domain of natural science; it has proposed new problems but it has held out the key to solve them. We should be untrue admirers of Darwin if we should forget that he regarded his suggestion as not universally applicable. At least in some parts of the subject of palæontology, as we have already remarked, one of the suggestions made by his predecessor Lamarck appears to be more satisfactory, because it brings out clearly two points of importance, response to surroundings and inheritance of acquired characters. From lack of time Darwin was unable always to measure precisely the exact degree of variation in the cases before him, but he often used rough and ready methods. Let us realize, however, that from these crude methods has sprung up a new science, biometry, which is engaged in investigating and measuring the most minute variations. It is characterized by the extreme of exactness.

When we look over the constantly lengthening list of works inspired by Darwin's genius, and gathered together under the heading Darwinian bibliography, we can appreciate the greatness of the service rendered by him in freeing science from the shackles of the dogma of constancy of species. In order to render this voluminous Darwinian literature readily available, it is divided into many separate groups, such as relations of flowers to insects, climbing plants and so on, and each of these groups is divided again, and many of them lead down or up to practical applications. Perhaps the most enticing of all the new fields thrown open to investigation by discarding the dogma, is that of purposeful breeding of plants and animals. In this great domain of research there are many workers, a few of whom, it is not ungracious to call somewhat ungrateful. Some of these ungrateful students indulge now and then in unfriendly criticism of particular views as to heredity assumed to have been held by Darwin. Such critics forget that if it were not for the help given by Darwin's search-light they would now be groping in darkness. Breeding to points, as it is called, deals with varieties under cultivation and domestication.

It must be unequivocally stated that from the time of Linnaeus down, variation and varieties have been recognized within the limits of species, but they had usually been regarded as so unimportant that they were practically ignored. They were considered by Linnæus playthings and profit-makers for horticulturists and nothing more.

The students of plant-breeding and animal-breeding in studying variation have rightly introduced some modifications of the original idea suggested by Darwin, and hence we have all sorts of new names for the different phases, such as Mendelism, Neo-Lamarckism, Neo-Darwinism, Weissmannism and the like. Verily, it does seem as if the strength of an article of faith is known by the schisms it keeps.

Two especially good results have come about scientifically from these studies of minute variations in biometry and eugenics. The first is that many varieties are now recognized as species in the making. Secondly, some of our acknowledged species are probably groups of species. Perhaps this admission may lead to too great a splitting up of established species. For instance, the species of American hawthorn, formerly counted by a couple of scores at most, are now counted by hundreds. But if the new so-called species are merely races, that is, established varieties, they are at least nascent species, and ought to have a place in the rcords. And further, it is no longer a misdemeanor in science to break up a species into its form-elements.

And now, in bringing this sketch to a close, let us confess frankly that the cause of variation, on which natural selection depends, is not yet positively known. That is the most important and inviting subject in biological science today.

Besides the liberating influences of Darwin's work on species, and its stimulating effect on all departments of biological inquiry, there is still to be noted the influence of Darwin's personal example of frankness, patience and magnanimity. It is good to remember that he would never indulge in controversy regarding his views relative to species. To be sure he had most valiant champions, who rather enjoyed a free fight, but he did not himself waste his time in discussion. He preferred to employ all of his scanty minutes

saved from the exactions of physical infirmity, for the nobler pursuit of Socratic questioning. Sometimes he asked questions of men, he was always asking questions of nature. Such an example of insatiable thirst for truth carries with it a profound influence for good, not only in science but in all departments of thought and in every-day affairs. Darwin's influence has been emphatically stimulating and wholesome. But, for a moment, let us ask what if his hypothesis which explains so much, but which from the nature of the case is unprovable, should hereafter be replaced by some new hypothesis on the whole more satisfactory? Of this at least we are positive: what has been done in this revolution cannot be undone; we never can go back to the dogma of the constancy of species.

It is worth while to reflect a moment upon an historical parallel which has been often cited and which will always stand as an object of comparison, namely, the discovery by Copernicus. Can we imagine what our sensations would have been on the morning when it was first seriously announced that the sun does not really rise, but merely appears to do so because the revolving earth turns toward it? It is difficult for us to realize the immensity of the shock of being thus commanded to change our views as to the entire order of the solar system. We should probably have resisted surrender as long as possible.

But, after a while, when it became clear that the hypothesis of Copernicus explained most of the phenomena of the heavens satisfactorily, we should have adjusted ourselves to the new conception, although we should have retained some of our former expressions in common speech, "the sun rises" and "the sun sets."

Here and there diligent search may find some person who holds that the accepted view as to the solar system is wholly wrong, and who maintains with the ancients that the sun *does* move and that the earth is flat.

But probably there is not today a single competent naturalist who looks upon species as permanent or fixed. That dogma disappeared when the Darwinian hypothesis compelled the scientific world to reëxamine the subject in the light of variation. That revolution in natural science has been complete.

THE INFLUENCE OF DARWIN ON THE MENTAL AND MORAL SCIENCES.

By GEORGE STUART FULLERTON.

It is my pleasant task this evening to dwell upon the influence which the life-work of Charles Darwin has had upon the development of a group of sciences with which men do not usually very closely associate his name. Darwin was a naturalist—his life was devoted in large measure to the investigation of certain of the phenomena of the material world, a world to which the highest of organisms as unequivocally belong as do the simplest forms of inorganic matter. But it was impossible that the eager and impartial curiosity of so great an observer should overlook anything so significant in the scheme of nature as is *mind*—the mind of the brute and the mind of man. We find in his works, as might be expected, profoundly suggestive thoughts on instinct and reason, on the ethical and the æsthetic emotions, on the social nature of man and the development of human society. These thoughts have, directly and indirectly, exercised an enormous influence in fields of investigation which, in the nature of the case, it was impossible that he should subject to systematic cultivation.

Darwin's opinions upon the topics to which I have alluded have been the subject of endless discussion. Heredity and environment, variation and adaptation, the struggle for existence and the survival of the fittest have become household words to those who study man, individual or social, as well as to those who occupy themselves with natural science in the usual acceptance of the term. The nature of my theme, and the time at my disposal, preclude the possibility of my setting before you in detail the views which Darwin has expressed on matters which lie within the field of the mental and moral sciences. His influence is not to be ascribed to the fact that he left behind him a certain collection of opinions, which are to be accepted or rejected individually. It has its main source, rather, in a certain

fundamental attitude, a point of view, which has proved so significant, so vital, so revolutionary, that its acceptance compels a world-wide change in the spirit and method in which we approach the sciences which treat of man. It is this point of view that I shall discuss in what follows.

The central and significant truth which Darwin and his followers have forced upon our attention is that man is literally and unequivocally to be given a place in nature, if we are to make him the subject of scientific investigation. It may be said: Has man not always been given a place in nature? To this I answer: Yes and no. It has, of course, been impossible to deny the palpable fact that man does exist on this planet, that he is to be assigned a definite time and place of being. But he who is acquainted with the history of human thought during the centuries past cannot but be aware that the place assigned to man in nature has often, indeed, has generally, been an equivocal one. The earliest Greek philosophy was, it is true, naturalistic; and it is also true that, in the centuries past, some form of naturalism has again and again come to the front. Nevertheless, we must remember that, on the one hand, these philosophies, while of speculative interest, remained relatively unfruitful in the explanation of concrete facts; and that, on the other, they were confronted with and influenced by a powerful tradition of a very different sort, a tradition which has always regarded man as a thing in some sense *in* nature, but not *of* it. I think it is not too much to say that, on the whole, pre-Darwinian science treated man as an equivocal thing. The sciences which occupy themselves with man grew up under the influence of preconceptions which have only within a generation been disappearing in the solvent of the new thought.

It is with some hesitation that one undertakes to describe in a few sentences the characteristic spirit of a given group of sciences at a definite time. There are always differences of opinion to be remarked. The old and the new, cautious conservatism and radical independence exist side by side. Nevertheless, to bring out clearly the extraordinary change, largely due to the influence of Darwin, which has come over the mental and moral sciences, I shall attempt a characterization, going back, first, to a time to which those of us

who are no longer young can easily think ourselves back; and, then, touching upon those sciences as they are at the present day. I forestall criticism by remarking that no one can be more conscious of the very impressionistic nature of the pictures which I thus draw with a few strokes than am I myself.

Can we not remember a psychology which no one attempted to treat as a natural science? A psychology which accepted a mind endowed with a certain group of faculties or powers, which seemed as ultimate, as irreducible, as little to be explained or accounted for as if the mind had been abstracted, fully developed, from some other universe than ours, and were incorporated in a tenement chosen at haphazard, which had to be accepted as serving its purpose passably well for a season? It was a psychology which lived in an atmosphere of abstractions, was inextricably mixed up with philosophical speculations, and took comparatively little note of the differences between minds, and the significance of such. It was a psychology to which the revelations of mind in the lower animals, the dawning intelligence of the infant, the aberrations from normal development discoverable in the idiot or the mentally deranged, the mental differences which characterize the races and peoples which cover our globe, remained relatively insignificant.

I do not mean to underestimate the science of psychology even at this stage of its development. But I wish to draw attention to the fact that such a psychology is little more than an attempt to describe, in its general outlines, a given type of mind, that of the normal, developed, civilized man. It accepts the characteristic of such a mind; it does not attempt to explain them; in treating mental phenomena in abstraction from the great organism of nature, it reduces the knowledge which it has to a body of facts robbed of a great part of their meaning.

Of æsthetics and ethics one may speak very much as I have spoken of psychology. The one concerned itself with beauty as it is revealed to man at a certain stage of his intellectual and emotional development; the other with his moral judgments, which were accepted as final, indisputable, inexplicable. To one of the most learned of British scholars, the ornament of a great university, it did not seem out of place, a few decades ago, to write a treatise

on morals after the pattern of a treatise on geometry. A few fundamental principles were taken up as having ultimate and unquestioned authority, an authority analogous to the definitions and axioms of a mathematical treatise; then the attempt was made to deduce from them a complete system of ethical maxims. As we peruse the volume now, we see in it, as in a mirror, the moral features of the character of the author. It is clear that he had arrived at a high stage in his ethical development, that benevolence, justice, veracity, obedience to law, and all the rest, were principles sacred to him—as they should be. And we can also see that he was a prudent man, with a wholesome tendency to check even good principles which seem in danger of running out into riotous excess. Does he not tell us unequivocally that the command "Thou shalt not lie," is absolute and unequivocal; and does he not, when in a later chapter he considers certain cases in which a strict adherence to truth would appear to precipitate grave disaster, prudently refuse to give us counsel, and leave us to the uncertain dictates of our bewildered conscience? How can we expect of him that he bring to an end a strife between two ethical principles, that of veracity and that of benevolence, equally independent, underived, ultimate, neither of which can abate one jot of its authority? In the nature of the case, our only refuge seems to be in an illogical compromise. Ethics, so conceived, can scarcely be called science.

Of the earlier condition of that science which studies man as organized into societies, a science which comprises a whole group of subsidiary sciences, there are others here better qualified to speak than am I. But it appears self-evident that, in so far as the nature of man is regarded as a thing to be accepted rather than to be accounted for, a limit is set to the province of explanation in all those sciences which concern themselves with the study of the social organism in its various phases and in the course of its development. That province is immeasurably widened when description is regarded as only a first step, the preliminary to a study of origins. It will be admitted by all that description once played a more exclusive rôle in the study of social phenomena than it does in our day.

That a revolution has taken place in the sciences upon which I

have touched so briefly must be evident to anyone acquainted with what is going on in those fields at the present time. The dominant idea which has controlled the progress which has been made, we owe to the genius of Darwin. That dominant idea is that the mind of man as well as the body of man must be treated as a natural phenomenon, making its appearance under given physical conditions; to be accounted for, as physical peculiarities are to be accounted for, by a reference to heredity and environment; a thing so intimately related to the body, that it must be looked upon as a function, an instrument significant in the struggle for existence, a something full of meaning, if accepted in its setting, but, torn from that setting, a riddle, a document in cipher, an unfruitful fact for science.

He who would be a psychologist today is compelled at the outset to realize that he is not studying that traditional abstraction, *the human mind,* with its traditional endowment of abstract faculties, but is studying mental phenomena as they are revealed in connection with a variety of organisms. He is forced to acquaint himself with anatomy and physiology, to study with especial care the senses and the nervous system of man. He is impressed with the necessity of supplementing the deficiencies of observation by an appeal to experiment, and he is introduced into a laboratory fitted out with an arsenal of apparatus, that would have inspired the psychologist of an earlier time with dismay. Moreover, it is dinned into his ears that no manifestation of mind must be neglected. He hears of animal psychology, child psychology, race psychology, pathological psychology, and the rest, until the magnitude of his task looms up before him and oppresses him with the boundlessness of his ignorance.

No man is more conscious of his shortcomings of the science of psychology today than is the psychologist himself. The air is full of strife, we are pressed upon on all sides by unsolved problems for which rival solutions are offered. Nevertheless, it cannot be denied that this science is gradually taking its place among other sciences which study the phenomena of nature, following with patient and painstaking effort the ofttimes weary road of observation, experiment, sober hypothesis and verification. He whose science may lead

him to reflect with curiosity upon the possible psychic life of micro-organisms, to stand perplexed before a case of dual personality, to note the resemblances and the differences which mark the mental life of the lowest and of the highest races of men, to contrast with these the evidences of intelligence betrayed by creatures which stand lower in the scale of life, cannot but be impressed by the fact that given manifestations of mind occur under given conditions, that mental phenomena are to be assigned unequivocally a place in the evolution of things. For him, the mind of a man, or the mind of a brute, is not an explained fact, for his science leads him as yet but a very little way; but it is an explicable fact, a *theoretically* explicable fact. He stands with confessed ignorance in the presence of many mysteries; but it is the fundamental assumption of his science that they are not hopeless mysteries; they are the mysteries of incomplete knowledge.

It will readily be seen even by a layman that this psychology is not the psychology of the pre-Darwinian thought. The old psychology has not merely grown, as all sciences may be expected to grow under the hands of their builders. It has been revolutionized. Mental phenomena are no longer phenomena at large, with no definite relation to any system. They are brought down from the empyrean and planted in the bosom of mother earth; where it, must be confessed, they seem to find a soil adapted to them, and where they show signs of a fertility in which they before appeared conspicuously lacking.

This modern view of the mind has been of far-reaching significance for all the sciences which treat of man, individual and social. Thus, the science of æsthetics regards as significant material the sentiment of beauty in its lowest manifestations as well as in its highest. It cannot permit the dictation of any one man, or accept as final the æsthetic judgment of any age or clime. It goes much deeper, and recognizes a relative justification for judgments the most diverse. Without denying progress, and without obliterating the line between the actual and the ideal, it sees in the divers standards of beauty which have been accepted or are accepted today, aspects of the evolution of the higher emotions, each significant in its place, having its rôle to play in the development of humanity, not to

be despised in any instance, but never to be accepted as a last standard which shall remain fixed and unchangeable.

The ethical philosopher has come to view his science from the same standpoint. He is concerned with rights and duties; man as he studies him is necessarily a social creature, standing in more or less complex relations with his fellow man. Man as a moral being is a constituent part of a greater organism, the family, the tribe, the state, humanity as a whole. The greater organism has a life history, somewhat analogous to his own; it is unfolding a life which, beginning with something relatively simple, comes to reveal in its later stages an indefinitely greater degree of complexity. It is to be expected that the rights and duties that express the relations of man to man in the social organism should take no new aspects as the relations themselves become more complex or come to be better understood. It is inconceivable that the same qualities of mind and character should, under widely varying conditions, call forth the same degree of approval, or be stamped as detrimental and to be discouraged. In other words, it is inconceivable that the social conscience should be an unvarying thing, unadapted to its setting, taking no note of those relations which are the very ground of its being. Moral codes must vary, if they are to be significant of the life of a community; actual ideals must be abandoned for better ideals, if men are to rise to more enlightened conceptions, and to embody them in a higher life. Ethics can reverence everyman's conscience, regarding it as the expression of the stage of moral development to which, for certain reasons, he has managed to climb. It can regard no man's conscience as infallible, inexplicable, an arbitrary limit to further development.

In speaking as I have of ethics, I have virtually described the attitude of the modern man to the social and historical sciences generally. It is impossible for me in the brief time at my command to dwell at length upon these disciplines. Suffice it to say that whether men are studying with the anthropologist, the differences which characterize races and peoples; with the sociologist, the general laws of the evolution of human societies, or the special institutions which are now the subject of such detailed and laborious investigation; with the historian, the life history of a community,

or of any class of men within a community;—the work is coming to be done under the control of the developmental idea. In seeking for the explanation of social phenomena, influences are much dwelt upon which once would have received little attention. Heredity, environment in the broadest sense, adaptation to new conditions, survival, these conceptions necessarily lie in men's minds, and give a direction to their efforts.

As I have said, the last half century has witnessed something very like a revolution in the field of the sciences which concern themselves with man. It may well be asked, why did not this revolution take place earlier? Was there nothing in an earlier time to suggest all this? to stimulate men to new and better directed efforts? I answer, there was much. He who is familiar with the history of philosophy knows well that there is scarcely one of the great controlling ideas of modern science, which has not had its forerunner in the thought of centuries gone by. Struck out like a spark from the brain of some bold and independent thinker, it has flashed for a moment upon the night and then has gone out. It has not kindled the lamp, the steady flame, in the light of which the world is now doing its work. Ideas can be born out of due time; unadapted to their environment, they fail to develop and bear fruit. Even a great thought may appear to us disembodied, a speculative audacity which does not stand unequivocally upon solid ground as a thing undeniable, unavoidable, necessarily to be reckoned with, as much an inhabitant of the real world as are we ourselves. Such thoughts can be ignored; they are seed cast upon stony ground.

Darwin's great service to science, as we all know, does not consist in the discovery of evolution, or even in the first suggestion of the doctrine of natural selection. It lies in the fact that he made fruitful what had been relatively unfruitful. His patient, cautious, scientific demonstration of the value of his ideas in furnishing concrete explanations of the phenomena of organic life, coming at a time at which the world was ready to understand what he had to offer it, precipitated the great battle the echoes of which can still be heard. He and his successors have made it impossible for us to revert to the thought of an earlier day. The new doctrine is with us, and stares back at us from the pages of scientific works in every

field. We cannot refuse to acknowledge it; it only remains for us to ask ourselves in what spirit we will admit it and adjust ourselves to it.

It is notorious that Darwin's work aroused serious apprehension and even bitter opposition on the part of many good people in his own time. It would be wrong for me not to dwell upon both aspects of the doctrine of the evolution of man and of human society, for both are actually of lively interest to those busied with the mental and moral sciences. The two aspects to which I allude are these: On the one hand, in treating man as a natural phenomenon, an explicable thing, we seem to be gaining much for science; on the other hand, in placing him in nature as a part of nature, we appear to degrade him from the high estate which the beliefs of the past have assigned to him—to make him, not a little lower than the angels, but a little higher than the brutes. I cannot refuse to discuss these things, for have I not contrasted rather sharply the mental and moral sciences as they were, and the same sciences as they are now, painting in no neutral colors the character of the modern investigator? It may fairly be asked whether the portrait is not too highly colored. Are there not those now busied with the study of man, in one or another of its aspects, who give but a qualified assent to the doctrine of evolution as it is coming to be accepted by many of their colleagues?

Let us dwell, first, for a few moments upon what men of the most diverse opinions must recognize as the attractive aspect of the doctrine. The idea of evolution has unquestionably proved a valuable instrument of investigation in every science which busies itself with man. Whatever mental reservations the man of science may cherish, whatever the limits which he may be inclined to set to evolution, he actually appeals to the principle in the interpretation of concrete facts. He finds that, in the light of it, the mind of man, his opinions, his emotions, his æsthetic judgments, his ethical codes, his social institutions—everything becomes luminous with a new significance.

Moreover, with an increase in comprehension comes a broader and a more intelligent sympathy. At any stage of his progress

man is what he is in virtue of his inheritance and his environment; it is not a matter of accident or of wholly inexplicable perversity that, at certain stages in the evolution of society, men are ignorant, limited in their sympathies, incapable of recognizing their own best interests. He who realizes this can see a relative good in that which the unenlightened will unhesitatingly condemn. There are those who have welcomed with enthusiasm the idea of the ascent of man, who have found it an inspiration to look into the future, to conceive of a development as yet faintly foreshadowed; a development from the standpoint of which man as he now is, limited in intelligence and in the control of himself and of the forces of nature, a creature of instinct and of impulse, climbing the hill before him stumblingly and with much waste of effort, will seem a creature to be pitied, a being whose feet are set on an upward path, it is true, but, nevertheless, one who is only at the outset of his journey, far from the regions of light toward which the development of humanity is tending.

The development of humanity, the gradual evolution of social systems, the idea of a historical order in which man has his definite place—are these not conceptions which protect the man who has really comprehended them against those radical proposals, so dear to men of quick sympathies and of ardent temperament, to make sudden and far-reaching changes in the social order, to forestall the slow course of natural development, and at once to confer upon us citizenship in some Utopia with all the advantages and none of the drawbacks of the world in which we actually find ourselves, and to which, as a matter of fact, we are moderately well adjusted? I shall not dwell upon these visionary schemes. They always are, they always have been, with us. It is no small thing to have in our hands an instrument of defence against the man who would make us perfect by violence, increase our stature by stretching us on the rack, drive us perforce into a land of milk and honey, when we cannot drink milk and are unfitted to subsist on honey.

So much for an inadequate sketch of one aspect of the doctrine of evolution, for the fruitfulness of the idea as an instrument of research, as a real help in pushing back the barriers of our ignorance, as the earnest of a hope for better things to come. And now for

a few thoughts touching what has seemed to many a less alluring aspect of the doctrine. In so far as we make man a part of nature, and treat his mind as we treat other natural phenomena, do we not deny his independence, the primacy which has been supposed to be his? Do we not rob him of certain hopes and aspirations, which men in the past have counted as very dear possessions? I cannot describe to you in a sentence the attitude of the worker in the mental and moral sciences toward this problem, for opinions still differ widely.

There are those to whom a frank naturalism is not repugnant; who accept man as a natural phenomenon, and trouble themselves little about the consequences. There are those who welcome the conception of the evolution of man, but wish to set limits to its scope. Something they would save out of nature, a spiritual principle, which they variously define, and of which they sometimes admit they can say little that is definite. There are those who, launching themselves upon the seas navigated by the speculative philosopher, announce to us discoveries that sound to the natural man like the tales told by early travellers. They inform us that the whole course of the evolution of nature, physical and mental, is spiritual throughout; that the only ultimate reality is mind, and that the world of physical phenomena which unfolds itself before our eyes has its source and being in the interaction of minds. I should not bring such a speculative view as this to the attention of a society which is composed of workers in the special sciences, were it not that it has recently had the endorsement of those to whom no one would deny the right to be called scientific men—among others, of the man who, I suppose, in the minds of a majority of those here present, would take his place as the leading representative of the scientific study of the mind now living in Europe. Lastly, there are those, and they happen to be popular leaders, who are in open revolt against science; and who try to save the freedom and independence of man by setting up a new standard of truth, and by refusing to recognize that this world is the orderly thing that science assumes it to be. These last, I think, science will scarcely take seriously.

In the foregoing, I have tried to give a fair account of the

direct and indirect influence which the life-work of Darwin has actually had on the development of the mental and moral sciences. I have endeavored not to obtrude my own personal views and predilections. But I cannot forbear, at this point, to ask whether, before deciding upon our attitude toward the doctrine of the evolution of man, it would not be wise for us to turn to history, and to consult the actual development of human thought in the past.

Again and again, when some new truth of wide significance has been discovered, or has come to be vividly realized, it has seemed to many dangerously revolutionary; it has presented itself under a threatening aspect. Nevertheless, the outcome has not been pure destruction.

The life of man has never been guided and moulded exclusively by the clear light of science. Religious aspirations, ethical values which have a traditional sanction and which have not been consciously evolved as the result of scientific thought, have in all ages acted as a support and a guide to life. The human mind refuses to be held wholly within the limits of what has been definitely and indisputably established—which limits, be it remarked, are by no means so far apart as, to the uninitiated, they seem to be. Man speculates regarding the ground of all things, he has aspirations which seem to reach beyond the span of existence which lies in the light of day before him.

Now, history has shown that, when any new advance in our positive knowledge has seemed for a while to work with destructive force against the ideas and ideals which have been of such high value to mankind, the result has not been, as a matter of fact, a destruction, but a readjustment, a broadening of view, a rise to higher conceptions and ideals. Religious aspirations and ideals, the conviction that ethical values are sacred and the life of man a thing to be treated with reverence—these attitudes have not been abandoned. We do not seem to have reason to think that the acceptance of the new evolutionary doctrine will banish them from the world.

Why, then, should we not freely and unreservedly accept the doctrine of evolution as the useful instrument it has proved itself to be in the sciences which concern themselves with man, and leave to the future the determination by actual experiment of any limits

to be assigned to it? Why not trust to the future readjustment which history teaches us to expect? Incidentally, it seems right to call attention to the fact that we live in our own age, and not in another; that the religious aspirations and the ethics of our age are the ones which practically concern us, and must guide our lives. The very doctrine of the evolution of man should teach us to be conservative as well as progressive; to realize that growth does not take place by a series of explosions; to see that our inheritance from the past and our actual environment cannot be regarded as without significance for human life. This is a practical matter upon which, in such a paper, I touch with due apologies.

Now that I am at the end of my paper, I think it is not out of place that I should make a personal confession of a natural human weakness; a weakness which will, I believe, be shared with me by many of those who are present. It is this: I dwell with the more pleasure upon the great and beneficent influence of Darwin, in that it is impossible to become acquainted with the life and character of this wonderful man, gifted in intellect, modest, open-minded, passionately sincere, free from envy and uncharitableness, a model for those who devote themselves to the investigation of truth, without being inspired with an affectionate admiration, and without feeling a certain joy in the fact that, after the long and bitter conflict precipitated by his ideas, the mists of misconception should have been cleared away, and his genius should meet with the generous recognition which is its due.

THE WORLD'S DEBT TO DARWIN.

By EDWIN G. CONKLIN.

(*Read February 5, 1909.*)

For centuries science has been engaged in glorifying the commonplace, in showing that natural phenomena are due to natural causes, and that the most stupendous as well as the most subtle phenomena, removed from us perhaps by almost an eternity of time and space, are but manifestations of continuous natural processes, which we may see and study for ourselves in the common phenomena of our daily lives. At every step in this progress science has had to contend with intrenched supernaturalism; in the beginning every happening, even the most trivial, was ascribed to some supernatural cause; to our ancestors it was self-evident that extraordinary occurrences required extraordinary causes, and that natural causes were wholly inadequate to accomplish great results. But step by step, before advancing knowledge of nature, supernaturalism retired from the plane of ordinary phenomena until she dwelt only in the misty mountain tops of origins, beginnings, creations; and day by day there was a growing respect for nature and her powers.

In this warfare of science with tradition there have been crises, turning points, no less important for mankind than any which are associated with the rise and fall of nations; such a crisis was reached when astronomy was emancipated from the thralldom of supernaturalism by Newton and Laplace; when geology was freed by Hutton and Lyell from the absurd cataclysmal theory, which virtually taught that age after age the creator, experimenting at world building, found the results not good, and so wiped them out and began again; but probably no similar crisis has had so profound an effect upon mankind as that revolution in our notions of the genesis of the living world which we associate preëminently with the name of Charles Darwin.

I.

Without doubt the greatest scientific generalization of the past century is the theory of organic evolution. The only other which can be compared with it, the doctrine of the conservation of energy, has not so profoundly influenced human life nor so greatly changed all the currents of human thought. Evolution has not only transformed biology, psychology, sociology, anthropology and geology, but it has given a new point of view to all science, art, and even religion. "The great theory of evolution," said John Fiske, "is rapidly causing us to modify our opinions on all subjects whatsoever."

Though many forerunners of this theory may be found in former centuries, its establishment upon a scientific basis belongs to the nineteenth century. How general the feeling is that evolution is the greatest scientific principle of modern times, and how almost universally its establishment is identified with a single man and a single book, is shown by the remarkable symposium which appeared in one of our magazines a few years ago.[1] Ten men, selected for their eminence in literature and education, were asked to give their opinions as to the most influential books of the nineteenth century. No one of these men was by training or profession a biologist, with the exception of one psychologist no one of them was especially identified with any natural science, and yet the only book of the century upon which all ten agreed was Darwin's "Origin of Species."

The doctrine of descent is so wholly in accord with the facts of biology, and indeed of all sciences; it is so reasonable and simple that one can scarcely believe that it had few adherents until after the middle of the last century. Yet the evolutionary speculations of the "Naturphilosophen," and even the more scientific hypotheses of Buffon, Lamarck and St. Hilaire in the first quarter of the century produced, on the whole, an unfavorable impression upon naturalists, and up to the year 1859 the problem of the origin of species, their relationships to one another, their geographical and geological distribution, was regarded as the "mystery of mysteries,"

[1] *Outlook*, December 1, 1900.

perhaps only solvable by the miracle of special and supernatural creation. Darwin wrote in his autobiography:

> It has sometimes been said that the success of the "Origin" proved "that the subject was in the air," or "that men's minds were prepared for it." I do not think that this is strictly true, for I occasionally sounded not a few naturalists, and never happened to come across a single one who seemed to doubt about the permanence of species.

In 1844 he wrote to Hooker:

> I have been now, ever since my return (from the voyage round the world), engaged in a very presumptious work, and I know not one individual who would not say a very foolish one. I was so struck with the distribution of the Galapagos organisms, etc., and with the character of the American mammifers, etc., that I determined to collect blindly every sort of fact which could bear in any way on what are called species. I have read heaps of agricultural and horticultural books and have never ceased collecting facts. At last gleams of light have come, and I am almost convinced (quite contrary to the opinion I started with) that species are not (it is like confessing a murder) immutable. Heaven forfend me from Lamarck's nonsense of a "tendency to progression," "adaptation through the slow willing of animals," etc.! But the conclusions I am led to are not widely different from his, though the means of change are wholly so. I think I have found out (here's presumption) the simple way in which species become exquisitely adapted to various ends. You will now groan and think to yourself, "on what a man I have been wasting my time and writing to." I should five years ago have thought so.

This single extract reveals the general opinions of naturalists on the subject of species before the publication of Darwin's work. We should never forget that in spite of all the theories and speculations on evolution which preceded Darwin it was still commonly believed before 1859 that species had arisen by supernatural creation, that the question of their origin was not therefore a scientific problem, but that it was the one great exception to the reign of natural causes in the natural world. It detracts nothing from Darwin's preëminent services to say that he was not the first to propose the doctrine of the evolution of species. What is much more important is that he was the first to establish it; he brought a dead speculation to life and gave it scientific standing, so that it is now accepted by practically everybody, and in all justice the credit of this greatest intellectual achievement of the past century belongs to him. The world-wide difference between Darwin and his pre-

decessors lay in the simple but all-important matter of evidence. They had proposed more or less possible and more or less reasonable hypotheses, but these failed of general acceptance for lack of evidence. Darwin brought to bear on the problem his great power and range of observation; he collected in his books such vast stores of facts bearing on his problem, that they are today the wonder and admiration of scholars; in masterly manner he coördinated the scattered and diverse evidence drawn from botany, zoölogy, morphology, physiology, embryology, ecology, palæontology, geology, agriculture, horticulture and animal breeding, and he presented the evidence with such force of logic, such clearness of exposition, such judicial candor, that he finally and forever overthrew the dogma of immutability of species and their special creation, and established in its place the doctrine of evolution.

The effect and influence of this work can scarcely be overestimated. Once Darwin had rendered acceptable to naturalists the doctrine of organic descent with modifications, it was found that it gave new meaning to the whole science of biology. Like a magic formula it solved the age-long problems of classification, affinity, good and bad species, aberrant and synthetic types; by it the mysteries of geographical and geological distribution were explained; by its guidance the records of the ancient world, as preserved in the rocks, were deciphered and correlated and missing links between many great groups of organisms found; in its light the history of the development of the individual from the egg acquired new significance. Physiology and psychology, no less than morphology, have felt its transforming touch, and not least among its results have been its revelations as to the nature, origin and relationships of man.

These stupendous results do not represent merely the frenzy of a new enthusiasm. There have been, of course, assertions which outran evidence, and skepticism which denied all evidence, but in spite of these excesses every year since 1859 has contributed in ever increasing measure to the more complete establishment of the doctrine of descent and to the wider extension of this theory into every field of human thought and endeavor.

The world's greatest debt to Darwin is for the work which he

did in establishing the theory of organic evolution, and this year marks not only the centenary of the birth of Darwin, but also the semicentennial of the publication of his greatest book, the "Origin of Species," which did more to establish that theory than any other book ever published. But it should not be forgotten that the world is indebted to him for much besides this. Darwin was one of the last of the great naturalists. He was the most painstaking and accurate observer and experimenter and he contributed largely to knowledge in several branches of science. He was a geologist of note and his works on volcanic islands and on the origin of coral islands alone would have given him a high place among geologists. He was a distinguished botanist and his studies on the fertilization of orchids, cross and self fertilization in the vegetable kingdom, insectivorous plants, climbing plants and the power of movement in plants, laid broad and deep the foundations for the study of physiological processes. He was a great zoölogist, as his volumes on the zoölogy of the expedition of the "Beagle," on recent and fossil Cirripedia, on the activities of earthworms, and on the variations of animals and plants, testify. His work on the "Descent of Man" shows the value of his contributions to the science of anthropology, and I have been told by psychologists that his volume on the "Expression of the Emotions" is one of the best and most fundamental of all works on this subject. Altogether he published twenty-two books (thirty-three, counting second and subsequent editions) and eighty-two papers and contributions. These statements indicate how broad was his mind, and how much of fact he contributed to science.

II.

Undoubtedly Darwin's most distinctive and important contribution to organic evolution is his theory of natural selection, or what has been generously, but unfortunately named "Darwinism." Although this was the chief corner stone in Darwin's evolutionary philosophy, it was not the only stone in that structure, as is the case with some of his followers. Darwin was broader than "Darwinism." He recognized more than this one factor of evolution, though he always believed natural selection to be the chief one.

I need not repeat here how Darwin was led to adopt this theory; how he found that selection on the part of the breeder was the factor which determined the course of transformation in domestic animals and plants; how, in his search for a similar factor in nature, the essay of Malthus on population suggested to him the elimination of the unfit and the preservation of favored races in the struggle for life; how for twenty years he had been developing this idea, when he received from Wallace, then in the Malay Archipelago, an essay on the same subject, and how this essay together with Darwin's sketch of his theory were presented simultaneously to the Linnæan Society on July 1, 1858—all this is now familiar history. It may not be so well known that at the semicentennial of the publication of these essays, held last July, Wallace, who was present, said that he had been given much more than his due in being called the codiscoverer with Darwin of natural selection, and that his share in the discovery should be proportional to the length of time which each had devoted to the subject, *i. e.*, about as one week is to twenty years.

Probably no scientific theory has been so widely and so fully discussed as has natural selection. On the one hand were those who, like Wallace and Weismann, maintained that it was the only and the all-sufficient factor of organic evolution; on the other hand were many who either denied that it was any factor at all, or who ascribed to it only a minor rôle. It was the ill fortune of the theory to have aroused profound theological opposition, which gave to the discussion an intense controversial aspect and which prevented a calm and unprejudiced judgment of the theory. Furthermore, the character of the theory itself invited discussion. It was based upon principles so general and familiar that everyone felt free and competent to discuss it, and as it was difficult to subject it to demonstrative proof it freed biologists as well as laymen from such uncomfortable restraints, and left much room for mere inference and speculation. Scientific principles are not established by dialectics and while this whole discussion has been immensely educative, it is doubtful whether its scientific results have been commensurate with the time and effort it has consumed. It is probable that the intense antagonism to the theory, chiefly on the part of men who were not

scientists, led to the exaggeration of the evidence for it and the minimizing of the difficulties to be explained. Certain it is that there has been much dogmatism on the subject, an over-confidence in certain hypotheses, and a general lack of scientific caution, which has led biology astray in some instances and has caused persons who are not biologists to accept insecure hypotheses as foundations for more elaborate specualtions; this is especially true in the fields of sociology and psychology. Dogmatism always begets skepticism and we need not be surprised to find that in recent times a few biologists have totally rejected natural selection as a factor of evolution. But I think we may be surprised at the intensity of feeling and the wholly intemperate attacks of some of the younger biologists upon this theory, and especially is this true in view of the fact that Darwin himself always avoided controversy and was one of the kindest and gentlest of men. Unfortunately the lack of judicial calm is quite as noticeable in these later attacks as in the earlier and less scientific ones.

Dennert says:

> Darwinism belongs to the past, we are standing at its death bed, and its friends are preparing to give it a decent burial.

Driesch also, with more scientific authority, but with no less spleen, says:

> Darwinism now belongs to history; like that other curiosity of our century, the Hegelian philosophy; both are variations on the theme: how one manages to lead a whole generation by the nose.

He calls it a new kind of religion, which would have done honor to Mohammed, and speaks of the softening of the brain of Darwinians. More recently, however, when Driesch addressed an English-speaking audience at Aberdeen, he was much more dignified and conciliatory and said, "Certainly natural selection is a *vera causa*" but he argues that it is a negative, an eliminating factor, and not a creative one.

It is surprising how persistent is the misunderstanding of natural selection, which is implied in this statement. The term "natural selection" was chosen, as Darwin says, because of its supposed resemblance to artificial selection, but it was so frequently misunderstood that he would have liked, if possible to have changed it to

"natural elimination," but he fondly hoped that in time everyone would come to understand it. Over and over again he recognized that natural selection was a negative, an eliminating factor. He never held that it was anything more than a sieve, as De Vries puts it, to sort out favorable from unfavorble variations.

The only difference of opinion between Darwinians and anti-Darwinians at present is a purely quantitative one as to the amount of value to be assigned to natural selection. It is perfectly evident that organisms which cannot live must die, and that those which are severely handicapped must, on the whole, perish sooner than those which are not so handicapped. No naturalist will question the fact that many ill-adapted forms are eliminated before they can leave offspring. The real question at issue is whether this elimination is severe enough to weed out all but the most favorable variations, as Darwinians generally assume, or whether it weeds out only the least favorable variations, as anti-Darwinians claim. If variations occur in all directions, as Darwin believed, natural selection must eliminate more than half of these in order to be a truly directive factor in evolution; and the less severe the elimination is the less directive is this factor. This may be illustrated by a diagram of a radiating figure in which the center of the figure represents the norm of a species from which lines, representing variations, proceed in all directions. If natural selection, or elimination, be represented by portions of a circle inclosing this figure and blocking the radii, then one quarter of the circle will block approximately one quarter of the radii; a semicircle, one half of the radii; three quarters of the circle, three quarters of the radii; and in general the more completely the circle (natural selection) blocks the radii (variations) the more directive it becomes. Many recent studies indicate that the elimination due to natural selection is not so extensive as Darwin and his followers believed, and that therefore it is not so important a factor in directing the course of evolution as they supposed. That Darwin himself was much impressed by some such consideration is shown by the statement made in his later works that he thought the most serious mistake which he had made was in attributing too much influence to natural selection, and too little to the inherited effects of environment and of use and disuse upon organisms.

Natural selection, or "Darwinism," is usually spoken of as if it were the only factor of evolution which Darwin recognized. As a matter of fact only three chapters of the "Origin of Species" were devoted primarily to this subject, whereas three were devoted to variation and its laws, and his great work on the "Variations of Animals and Plants," which he omitted from the "Origin" merely to make the latter a shorter and more readable account, occupies two large volumes. It is particularly unjust and untrue to say that Darwin's theory of evolution recognized only the negative factor of elimination. In reading the criticisms of Darwin's theory one cannot fail to be impressed with the fact that many of the critics do not know Darwin's works. Let us hope that one of the results of the Darwin anniversaries which are being held this year throughout the civilized world will be to induce people generally, and the critics in particular, to read and re-read Darwin's books.

I confess that every time I look into his books it is with some new feeling of surprise and admiration. How thoroughly modern they are in most things! Apparently they might have been written after the promulgation of Neo-Lamarckism, Neo-Darwinism, mutation, orthogenesis and other modern theories, and one feels inclined again and again to look critically at the date of the book. It is an interesting fact that most of the objections which have been advanced in recent years to the Darwinian factors, were considered at length by Darwin in later editions of the "Origin," and it is amusing to read these modern objections and then find the answers to them given by Darwin himself in calm, judicial and convincing manner. One who knows Darwin's works can understand and in a measure sympathize with the enthusiasm of Emerson for Plato, when he said, "In Plato are all things, whether written or thought."

The positive side of Darwin's theory, and indeed of every other theory of evolution, is the variability of organisms, and the principal question which confronted him, as it confronts every evolutionist today, was this—"What is the nature and what are the causes of variation?" Darwin devoted many years of intense labor to the study of this problem and in his many volumes he brought together a larger amount of information on this subject than has ever been collected by any one man before or since. He concluded that the

causes of variation are in the main these: (1) The influence of the environment and of changed conditions of life (2), the effects of the use and disuse of parts, (3) the organic correlation of one variation with another so that the two necessarily arise together. Again and again he asserts as one of his principal conclusions, which he makes especially emphatic by placing it at the head of certain chapters, that "variability of every kind is due to changed conditions of life." He considered the value of sports, or what De Vries calls "mutations," in the production of new races, and he decided that their value was not usually very great. He considered the question as to whether variations occur in every direction, or principally in one, whether they are multifarous or unifarous, and he concluded on the whole that the evidence was chiefly favorable to the former view.

It is in these three directions that our knowledge of the origin of variations has made the greatest advance within recent years, viz., (1) The effects of the conditions of life in producing new races, (2) the value of sudden sports or mutations, (3) the question whether variations are fluctuating or definitely directed. All of these factors were considered by Darwin and to the first he assigned great importance; and if the evidences now to be had show that the second and third factors named are more important than he supposed, they do not fundamentally nor seriously change his theory. In some quarters there is a tendency to hail the mutation theory of De Vries and the orthogenesis theory of Eimer and Whitman as antagonistic to the Darwinian theory, but there is absolutely no reason why all of these factors may not coexist harmoniously. Both De Vries and Whitman hold that natural selection is a factor, and an important one, in the evolution of organisms, and if the theories of mutations or orthogenesis shall prove to be well founded, the whole problem of evolution will be immensely simplified and the greatest objections to the Darwinian theory will disappear, viz., (1) The lack of sufficient time for evolution, (2) the paleontological evidence that evolution has been in directed lines, (3) the inutility of many specific characters, (4) the complete disappearance of many rudimentary organs, (5) the harmonious coadaptation of parts.

III.

Darwin's theory of evolution includes much more than the doctrine of descent; it attempts to explain by natural causes the wonderful and exquisite adaptations of organisms to their conditions of life. The deepest and most mysterious problems of biology do not center in the structure of organisms, nor in their functions, nor even in their oigin, but in their fitness. Everywhere the universe is a cosmos and not a chaos; "Order is heaven's first law;" but this order is especially evident in the organic world. The subject of organic adaptations is undoubtedly a dangerous one for the scientist, full of pitfalls for the unwary and with many alluring calls to metaphysical speculation, but it is a subject which lies in the background of every biological problem. "Life is," as Professor Brooks taught, "response to the order of nature," and it is the element of useful, apparently purposive, response, which more than anything else distinguishes the living from the lifeless, and separates the methods of biology from those of chemistry and physics. Indeed Herbert Spencer defined life as "continuous adjustment of internal relations to external relations"; lack of such adjustment invariably leading to death.

One cannot speak of any organ or tissue of an animal or plant without illustrating such adjustment. Consider the fitness of the skeleton for support, of the muscles for contraction, of the alimentary system for digestion and absorption, of the heart with its valves for pumping and the blood vessels for circulating blood. Consider the truly remarkable contrivances for insuring cross-fertilization in animals and plants and for the protection and nourishment of the young. Consider the fitness of the nervous system for receiving and transmitting stimuli; the fitness of the eye for seeing, of the ear for hearing, of the tongue for tasting. Think of the fitness of every organ for its particular use, and then consider the peculiar fitness with which these organs are coördinated into an harmonious whole. Viewed in this light, "What a piece of work is man," or any other organism!

Such adaptations to general conditions of existence are so common that to most persons they do not seem remarkable, while some peculiar adaptation, such as the leaf insect, or the Venus fly-trap,

seems wonderful simply because it is not common. Many of these more uncommon adaptations have played an important part in the discussions of the various theories of evolution which have been advanced during the past century. As illustrations of adaptations to particular conditions of life may be mentioned the fitness of horses' limbs for running, those of seals for swimming, those of birds for flight. Innumerable adaptations are found, also, among animals and plants, for offense and defense, such as the sting of the bee, the poison of serpents, the tusks, horns and armor of many animals, the well-known structures and habits of the porcupine, the rattlesnake, the opossum and the skunk. Again many animals, such as the stick insect and the dead-leaf butterfly, are so like the objects upon which they are commonly found that it is difficult to detect them even when searching for them.

The ability which many eggs, embryos and adults have of restoring lost parts, and in general of resuming the typical form after injury constitutes another class of fitness which is of the greatest interest. Most remarkable also are the adaptations which certain organisms show to desiccation, to extremes of temperature and to various poisons. In particular the adaptations of organisms to bacterial poisons and to snake venom, where every kind of poison leads to the formation of a particular kind of anti-body which counteracts the poison, are among the most surprising known.

The list of such fitnesses it well-nigh endless and the question of their origin forms one of the most striking and fundamental problems of biology. How have lowly organisms learned to utilize processes of chemistry and physics so subtle that intelligent man only after centuries of civilization has come only to the place where he can appreciate these processes but cannot duplicate them?

Innumerable attempts have been made both by philosophers and biologists to find a natural explanation of this fundamental phenomenon of life. One need only enumerate the "perfecting principle" of Aristotle, the "active teleological principle" of Kant, Lamarckism, Darwinism, several kinds of selection, and finally the "entelechy" of Driesch to indicate over what a field these explanations have ranged.

If for the present we disregard those views which really attempt

no causal explanation, but merely restate the mystery in terms of perfecting principles or entelechies, and those which find the causes of adaptations in unknown laws of variation, there remain two attempted explanations of organic fitness which may be known by the general terms of Lamarckism and Darwinism. Lamarckism is a theory which attempts to explain racial adaptations as the result of the inheritance of individual, acquired adaptations. It is well known that extrinsic and intrinsic changes frequently produce adaptive modifications in organisms, and Lamarckism maintains that these individual, somatic modifications are ultimately inherited and that in this way adaptations, characteristic of a race or species, arise. Thus all inherent or germinal adaptations are supposed to be derived from acquired or somatic ones. How these individual somatic adaptations arise in the first place Lamarckism does not undertake to explain; the adaptive character of the response of an organism to its environment, to use and disuse, and to its needs, remains as much of a mystery as ever. As we know Darwin believed that some individual adaptations, especially those which resulted from the use or disuse of parts, might be inherited and thus become racial or specific. This theory if true would afford a good explanation of inherited adaptedness; unfortunately there is no evidence that such acquired adaptations are regularly inherited. For years this evidence has been earnestly sought but no such confirmations have been found as would certainly have been the case if this kind of inheritance were at all common.

Modern Darwinism, on the other hand, rejects the possibility of the inheritance of such acquired adaptations, and maintains that there is no genetic connection between acquired and inherent fitness. It maintains that all adaptations are due to multifarous variations among offspring and the elimination by natural selection of those which are poorly adapted. All adaptations which are for the good of the species rather than of the individual, admit of no other natural explanation; such adaptations could not have arisen from adaptations acquired by an individual as Lamarckians assume, since they benefit the species at the expense of the individual. Darwin showed in masterly manner that the continual elimination of the unfit and the preservation of favored races would gradually improve the stan-

dard of fitness until such exquisite adaptations as are found, for example, in the case of the eye might be reached; many persons now doubt the omnipotence of selection, but if to natural selection there be added some such factors as orthogenesis or mutations most of the inherited adaptedness of animals and plants may be so explained. This seems to me to be the crowning feature of Darwin's great theory; it is not so much its species-forming power which impresses me as its ability to explain on simple and natural principles very many of the wonderful adaptations of the living world.

On the other hand it must be admitted that there is one entire class of adaptations which natural selection, as held by Darwin, is unable to explain. Neither Darwinism, Lamarckism, nor any other mechanical explanation hitherto proposed is able to explain satisfactorily all the equally wonderful acquired, individual, or somatic adaptations of organisms. All scientific theories of evolution hold that racial adaptations are due to experience; Lamarkism, that they are the directly inherited effects of individual experience; Darwinism, that they are the indirect results of experience, through the presentation of many variants to the action of selection and the survival of the best adapted. Neither of these theories could explain sudden adaptations to conditions never experienced before; and yet some individual adaptations are apparently of this sort. Bear with me while I mention some of these cases which have been held by several recent writers to be fatal to Darwinism. It has been found that if the lens of the eye of a newt is removed it will be regenerated perfectly within a few weeks. Now it may be assumed that such an injury as this, involving as it does a very delicate surgical operation, never took place in nature, and yet pure Darwinism can explain this regeneration only by the supposition that the loss of the lens has taken place so frequently among the ancestors of present newts that they are perfectly adapted to this injury. Again the eggs, embryos or adults of many animals may be cut or broken into fragments or otherwise injured in such ways as could never have occurred in nature, and yet these fragments will in many cases give rise to perfect animals, "as if the pattern of the whole existed in every part." This power of regeneration cannot be the result of past experience, since there is no constant relation between it and

liability to injury. Other contingent, individual adaptations of a still more striking kind are found in the acclimatization of organisms to certain poisons, particularly bacterial poisons and snake venom. It has been shown that, as an antidote to these toxins, various antitoxins are formed, and for every toxin, or at least for every toxalbumen its own particular anti-body. Now many of these poisons are of such a sort that it is perfectly certain that the immediate ancestors of the forms poisoned could never have experienced them, and yet the response is as perfect as it could be if it had been due to long experience. Many other similar cases might be cited if time allowed, but these are enough. The apparently intelligent and purposive response of an organism to a stimulus or environment which it has never experienced before is one of the most mysterious and fundamental problems of biology.

There are, therefore, adaptations which neither Lamarckism nor Darwinism nor any other system so far proposed can explain satisfactorily, and this has led several biologists, notably Wolff and Driesch, to the conclusion that these theories "fail all along the line." But this conclusion appears to me hasty and extreme. There are many adaptations, as we have seen, which may be beautifully explained by the Darwinian theory, viz., all racial or inherent adaptations which are not first called forth by the contingent stimulus to which they are the appropriate and useful response. On the other hand adaptations of the latter sort are problems of physiology rather than of phylogeny. One of the greatest needs of biology is for more detailed and accurate information regarding them; we must know exactly what happens in each case, the physiology of the response irrespective of its usefulness, and then perhaps the latter may find an explanation. It is certainly premature to abandon hope of finding a natural and causal explanation of such phenomena, as Driesch and Wolff do, before we are really acquainted with the phenomena themselves.

Some of these contingent adaptations probably belong to the fundamental and original properties of living things and as such are not to be explained by any theory of evolution; for it must not be forgotten that organic evolution is a theory of transmutation which undertakes primarily to explain the diversity which exists

in the living world, but not the original properties of life. It undertakes to explain the various forms of adaptations found in the living world, but not protoplasmic adaptability. If life is "continuous adjustment of internal relations to external relations," as Herbert Spencer held, then life is adaptability, and it would be unreasonable to demand that any theory of organic evolution should explain the origin of this.

It may be that regulation or regeneration is one of the fundamental physiological properties of living things and that it belongs in the same category with assimilation, growth, metabolism, reproduction and irritability, properties which are found in the lowest organisms as well as the highest, and which can therefore be left out of the list of those things which evolution may reasonably be expected to explain.

On the other hand it seems possible that many contingent, individual adaptations may find a natural explanation in the further extension of the selection principle to the physiological responses of organisms and to the more elementary parts of which their bodies are composed. If to the natural selection of Darwin ("personal selection") there be added some such principles as the struggle of the parts ("histonal selection") of Roux, the "germinal selection" of Weismann and the method of "trial and error" of Jennings, many adaptations, otherwise inexplicable may find a natural explanation. Weismann's views have been frequently condemned because of their highly speculative character, but it cannot be denied that he has shown profound insight into the most fundamental problems of biology, and in many instances he has seen his speculations verified by subsequent research. In a masterly series of works Jennings has proved that the adaptations shown in the behavior of many lower organisms may be reduced to the simple principle of "trial and error," or the rejection of unfavorable motor responses; in this way aparently purposive behavior, which Binnet supposed to be due to the relatively complex "psychic life of microörganisms" has been shown to be due to a few simple motor reflexes, which are repeated indefinitely until they bring the organism into a favorable environment. Darwin himself suggested this explanation of the apparently intelligent behavior of the earthworm, and Jennings has shown

that it is applicable to the behavior of a large number of animals. This principle of "trial and error" is in reality the rejection or elimination of unfit responses during the individual life of an organism, and if a similar principle should be found to be applicable to other physiological processes it would probably explain in equally simple manner many apparently purposive responses which are at present inexplicable. Thus the simple principle of the elimination of the unfit, whether of individuals, or of parts of individuals, or of physiological responses, would offer a possible and natural explanation of the almost universal occurrence of fitness in the living world.

But whether the Darwinian theory is capable of explaining all the fitnesses of organisms or not, it does succeed, as no other theory does, in offering a natural and causal explanation of very many of these wonderful phenomena. The development of particular structures and functions to meet particular conditions of life, such as organs of locomotion, sensation, digestion and reproduction; organs and instincts of protection, offense and defense; and all the multitudes of diverse forms and ways in which organisms are fitted to carry on the fundamental properties of life amidst the most varied conditions—these diversities we may reasonably expect a theory of evolution to explain, and it is the crowning glory of Darwin's theory that it is, on the whole, able to explain them.

IV.

This is a brief review of Darwin's most important work. Some of his generalizations have been and still are of the greatest importance, others were of less value and have since been abandoned. In this respect his work is not unlike that of other scientists, and yet we all recognize that Darwin occupies a unique position in biology; that indeed he stands almost alone in the greatness of his influence on the world, and that his name can be properly associated only with that of Sir Isaac Newton, by whose side he lies in Westminster Abbey, and with two or three others in the whole history of science.

What is the secret of the tremendous influence which Darwin has had upon the entire world? He was of course a remarkable man, remarkably well prepared for a supremely great work. Keen

observer of nature in many lands, gifted with unusual ability in collecting, weighing and systematizing facts, endowed with a fertile imagination and with great powers of generalization, and yet cautious, slow in reaching conclusions, honest beyond all others, a man who worked every day of his life to the limit of his strength—none like him had ever before grappled with the mysteries of creation.

But apart from his own peculiar fitness for this work Darwin was unusually fortunate in his opportunity and his environment. The world was ready for him. Lamarck, St. Hilaire, Mendel addressed a world not ready to receive their messages. But in 1859 the need of some natural explanation of the origin of species was keenly felt and many naturalists were groping in the dark for some rational solution of this problem. In his autobiography Darwin says in explaining the success of the "Origin of Species":

> What I believe is strictly true is that innumerable well-observed facts were stored in the minds of naturalists ready to take their proper places as soon as any theory which would receive them was sufficiently explained.

The problem itself was one of the greatest which had ever been raised in the history of science. Step by step miraculous intervention in nature had been eliminated and supernaturalism had been driven from astronomy and geology and embryology and had taken its last great stand on the special creation of species and the supernatural origin of adaptations. To many people evolution seemed to be an atheistic attempt "to drive God entirely out of his universe." It presumed to determine man's place in nature, and many believed that if man were descended from the beasts which perish he could not be a son of God. It has been said that there are two subjects in which all people are interested—theology and politics. Evolution certainly caused a disturbance in theology and it accordingly came as a shock to all Christendom. The necessity of defending it before the public converted scientists into controversialists, and probably no scientific theory before or since ever received so much popular attention.

Again Darwin owed very much to his friends, especially to Lyell, Hooker, Huxley and Asa Gray. The idea of fighting for his theory seems to have come to him only gradually after the first shock of the

brutal assaults upon it. Six months after the publication of the "Origin" he wrote to Hooker:

> I look at their attacks as proof that our work is worth the doing. It makes me resolve to buckle on my armor. I see plainly that it will be a long uphill fight. But think of Lyell's progress with geology. One thing I see most plainly, that without Lyell's, yours, Huxley's and Carpenter's aid, my book would have been a mere flash in the pan. But if we all stick to it we shall surely gain the day. And I now see that the battle is worth fighting.

Many a discovery, like that of Mendel, is launched meekly and modestly into the world, to sink to oblivion or to be lost from sight, only to be rediscovered at some future time. Not so with a militant truth; it challenges and demands attention, and in the case of Darwin's theory it richly deserved it.

Next to his friends Darwin owed most to his enemies; the attacks upon him and his theory were so violent, so brutal, so out of reason, that his own sane, calm and absolutely honest course shone with all the more luster. To these unreasonable attacks and to the same reaction which was bound to follow, Darwin, as well as his great contemporary Lincoln, owed very much.

But wholly apart from these circumstances which contributed only temporarily to his reputation and influence, Darwin stands as one of the leaders of science for the great work which he did; work of lasting value which has not yet been outgrown and which can never be forgotten. He stands as a leader in science because of the methods of his work; he was so broad and science has since become so specialized that we can never hope to see his like again; he was so honest in dealing with objections to his theories and so sane in judgment that he was never carried away by his own enthusiasm; above all he was so patient in his work that his example may be especially commended to this impatient age; on every one of his principal works he spent from five to twenty years of the hardest labor of which he was capable, and it is not to be wondered at that this work has lasting value. Charles Darwin stands today and will continue to stand for years to come as one of the most impressive and influential figures in human history.

Mr. President: I beg leave to introduce the following minute:

On this hundredth anniversary of the birth of Charles Darwin,

the American Philosophical Society, in common with learned societies throughout the world, desires to record its high appreciation of this illustrious man and of his inestimable services to science and to the entire intellectual world; it recalls with satisfaction that he was for thirteen years before his death a member of this society, having been elected in 1869; that his grandfather, Erasmus Darwin, was also a member; that his son, Sir George Darwin, is a member of this society, and that on the occasion of the bicentennial celebration of the birth of Franklin, our founder, he was present as the bearer of fraternal greetings from the University of Cambridge, the Royal Society, the Royal Institution of Great Britain, and the British Association for the Advancement of Science; and that by his scientific addresses on that occasion, as well as by his presentation of Medalions of Erasmus Darwin and Josiah Wedgwood, grandfathers of Charles Darwin, he strengthened the bonds which connect the American Philosophical Society with the immortal name of Darwin.

PRINCETON UNIVERSITY.

RICHARD ALEXANDER FULLERTON PENROSE, M.D., LL.D.

(*Read January 15, 1909.*)

Richard Alexander Fullerton Penrose, son of the Honorable Charles Bingham Penrose and his wife, Valeria Fullerton Biddle, was born at Carlisle, Pennsylvania, the 24th of March, 1827. He was graduated in 1846 at Dickinson College, where he received also the degree of doctor of laws in 1872. After completing his college course, he entered the Medical Department of the University of Pennsylvania, and graduated in 1849. From 1851 until 1853 he was resident physician at the Pennsylvania Hospital; in 1853 he became physician to the Southern Home for Children, and in 1854 consulting physician at the Philadelphia Hospital. He was one of those who secured the opening of the wards of the hospital for instruction. He delivered clinical lectures there on diseases of women and children. He also lectured on obstetrics in the Philadelphia School of Medicine, being associated with Da Costa, Agnew, Darrach and Hewson. In 1856 he was one of the founders of the Children's Hospital, and contributed to it time, energy and money. With Levick and Hunt he founded a successful and a very profitable quiz association.

In 1863 the trustees of the University of Pennsylvania elected him to the professorship of obstetrics and diseases of women and children, made vacant by the resignation of Dr. Hugh L. Hodge. He occupied the chair until 1889, when he voluntarily retired from the position, and at the same time gave up active practice.

It was as a medical teacher that Doctor Penrose was known. It was his life work. As he acquitted himself in his chosen field he should be judged. It is by this standard he himself would wish to be judged. In estimating his success we must remember the limitations imposed upon him. Medical education in America was in a stage of development so different in his time from the present that

it is difficult even for those of us who have witnessed its evolution, to realize its crudity and provincialism. Our medical schools were mainly proprietary institutions conducted for financial profit. Laboratory facilities, clinical material and individual instruction were either lacking altogether, as in the department of obstetrics, or were just beginning to be provided in the other two principal subjects of a medical course, medicine and surgery; but provided so inadaquately that the student, obliged to go abroad to complete his education, could not justly be surprised at the contempt with which his medical diploma was regarded in Europe. The proprietors of our medical schools were quite satisfied that they had fulfilled their whole duty if they furnished a lecture room for a few hours a week to the teachers of the most important subjects in the course. The didactic lecture was the accepted method of medical teaching. Anything else that was offered was subordinate to it. These were the conditions in the very best of our schools and it was under these conditions that Dr. Penrose was obliged to teach. The only means at his command to prepare his students for their future responsibilities, was the didactic lecture. But of this means he availed himself with consummate ability.

It is no exaggeration to say that none of his contemporaries made his lectures at the same time so instructive, entertaining, amusing and useful. The most admirable quality of his art was the vivid and lasting impression made upon his auditors.

Much as we admired the skill, the operative dexterity, the sound judgment, and the great experience of Agnew, the profound erudition of Leidy, the brilliancy of William Pepper, all of Dr. Penrose's old students will bear me out in the assertion that today, twenty years at least, after they were given, we remember his lectures more distinctly than those of any of his colleagues.

In the swing of the pendulum from the old to the new methods our present tendency is perhaps to neglect the didactic lecture too much. It can be utilized with advantage still. The medical teacher of today could not do better than to study the methods of a man like Penrose who was obliged to concentrate all his ability on the only means of teaching at his command.

His personal dignity, penetrating but kindly voice, exquisitely

keen sense of humor, poetic fancy and eloquence were inimitable. But certain rules of the art might be learned by a study of Penrose's lectures. They were as carefully prepared as an actor studies his part. Emphasis, inflection, gesture and expression received scrupulously careful attention. A judicious admixture of the gay with the grave relieved the tedium of an hour's address. Each important point was brought out in bold relief, sometimes by a certain circumlocution in its introduction, often by an amusing anecdote, again by unexpected antitheses or apparent paradoxes and occasionally by moving his audience at one moment to roars of laughter and at the next to a hushed and solemn silence.

I cannot confine myself, Mr. President, to a cold analysis of Dr. Penrose's qualities as a medical teacher. Many of his fellow members in this venerable society were his personal friends and I am proud to be numbered among them. They must expect to hear, as I feel it my duty to pay, an inadequate tribute to the man himself. His oldest brother was described as the "kind and amiable Penrose." The description is equally applicable to the younger brother. He fairly radiated kindliness. A harsh, unkind or ungenerous thought was absolutely foreign to his nature. He was affable, courteous, cordial to all degrees of men; but a consciousness of distinction in birth, connections and position gave him an innate dignity which forbade undue familiarity or lack of respect.

He had some odd and whimsical views on men and things, giving his conversation a fascinating piquancy. In one of his amiable foibles, he was like that most lovable character in fiction, Colonel Newcome. His friends were perfection itself. He could see no fault in them. His enthusiastic partisanship for people he liked reminds one of Essex endeavoring to secure the attorney generalship for his friend Bacon and saying to Sir Robert Cecil, "I will spend all my power, might, authority and amity, and with tooth and nail procure the same for him against whomsoever."

An incident in our association illustrates what I mean. He had determined to do all in his power to make me his successor. As the first step in that direction he told me to prepare a lecture as carefully as I could and to commit it to memory. When it was ready I was given a letter dated two days later, ostensibly received

just before his lecture hour, and reading, "I am unexpectedly detained. Please inform the class. If they care to stop and listen to you, you may use my hour." I was instructed to enter the room in apparent confusion, making the open letter in my hand tremble; to mount the rostrum and after giving the class Dr. Penrose's message, to say in a hesitating voice, "If you are willing to stay and hear me, I have a word or two to say on an interesting subject." "They will stop to hear you," said Doctor Penrose, "in the expectation of seeing you make an exhibition of yourself." His little plot was carried out exactly as he had planned it. My lecture was well received and Penrose was hugely delighted at its success.

I could give many more examples of characteristic kindnesses to younger men whom he befriended with a bounteous generosity that knew no stint.

There is no excuse for melancholy in contemplating such a death as Penrose's. Retiring in the full possession of his faculties and in the enjoyment of an enviable reputation; at an age when there was no premature retreat from the battle of life to an inglorious ease, but when he had earned the right to repose; followed into his retirement by the affectionate regard of hundreds of pupils in all parts of the world; living a score of years in tranquillity and peace; exceeding the allotted span of life by more than a decade; surrounded by devoted friends and a loving family, I can imagine no more dignified end of an honorable career. We can feel only the sadness with which we, who were left behind, might view the departure of a valued friend on a long and prosperous journey. When we leave this mortal ark behind and answer "Adsum" at our last roll call, may our survivors say of us, what we can say of our departed friend: "the sweetest canticle is *nunc dimittis,* when a man hath obtained worthy ends and expectations."

BARTON C. HIRST.

DANIEL COIT GILMAN, LL.D.

(*Read February 19, 1909.*)

Daniel Coit Gilman, the first President of the Johns Hopkins University, was born in Norwich, Connecticut, July 6, 1831, of native New England stock. His early education was obtained in the town of his birth, until at the age of fourteen he removed to New York. Three years later he entered Yale College where he ranked well, though not among the highest, and was active in all that concerned the literary and social life of the community. Toward the end of his course he became interested in lexicography, and after graduation spent a year at Harvard College with the idea of preparing a new English dictionary. At Cambridge he lived in the house of the geographer Guyot and was brought under the influence of the elder Agassiz, an influence that materially affected his plans for the future and shaped, to no small extent, his views on education. From this time his interest in a dictionary began to give way to the larger demands of literature and education, a change of purpose that was rendered permanent by an opportunity, rarer in those days than now, of enlarging the scope of his observation and knowledge by means of foreign travel and of coming into contact with the culture and experience of the old world. In 1853 he and his college friend, Andrew D. White, were invited by Gov. Seymour of Connecticut, recently appointed Minister to Russia by President Pierce, to go as attachés to the American Legation at St. Petersburg. The opportunity thus furnished was utilized by Dr. Gilman not only in obtaining a certain amount of diplomatic experience, but also in extensive travel in England, Germany, France, and Russia, in meeting men of distinction, and wherever possible in investigating educational conditions. His correspondence at this time, both public and private, shows that he was visiting foreign libraries and institutions of learning, and was widening the range of his inquiry by studying the attitude of European States toward morality and phil-

anthropy and particularly toward training in technical and scientific schools. The thoroughness and breadth of his investigations appears in the paper entitled "Scientific Schools in Europe," published on his return in Barnard's *Journal of Education,* and the direction which this study gave to his own thoughts can be inferred from the appeal therein made for such scientific education in America as would make it unnecessary for "scores of young men" to visit Europe annually "to pursue those special courses of instruction which are there so liberally provided." The three years' residence abroad aroused in the mind of this young man of twenty-four his first definite understanding of the needs of education in America and of new reaches in the world of scholarship. Higher courses of instructions became to him the great need of the American college. "A school" he said, "which, rising above those common places which are everywhere known, should supply an education of the most elevated order and should stimulate original inquiries and investigations, would confer unspeakable benefits upon every portion of our country and would not be without its influence upon the progress of humanity." Herein is expressed the essential educational principle that was destined to play so conspicuous a part in Dr. Gilman's educational program; and herein lies the germ of the Johns Hopkins Universitly. The idea was not peculiar to Dr. Gilman. As he himself said, "Throughout the civilized world the improvement of universities was engrossing the attention of the wisest men and the most enlightened states;" but the important fact remains that among the first of the wisest men was he whose three years sojourn abroad had given him a clue to the solution of the problem.

Returning to America in 1855 Dr. Gilman was appointed assistant-librarian and afterward librarian of Yale College, a position he held until 1865. At the same time he became chairman of the visiting committee of the public schools of New Haven, secretary of the State Board of Education, and co-editor with Henry Barnard of the *Connecticut Common School Journal.* He travelled about the state visiting schools and acquiring such information as to justify his sharp and trenchant criticisms of the existing system. His report abounds with suggestive statements: "Bricks and mortar

however put together cannot make a good school;" "Versatility is far less valuable than thoroughness;" "The first and most important point is to train the mind, to educate the judgment, the reason, the memory, the imagination, and the second and subordinate object is to convey such knowledge to the scholar as may be useful to him in life." During this period he satisfied his lexicographical interest by assisting in the revision of Webster's Dictionary, and disclosed a new specialty by preparing, in conjunction with Professor Guyot, a series of school geographies and maps. Another trip to Europe in 1857 supplemented the observations of the previous visit.

In 1863 Dr. Gilman was appointed professor of physical geography in the Sheffield Scientific School, and two years later he resigned his position as librarian, a vocation that he was not destined to resume. Though fully appreciative of the significance of library training and organization, as is evident from his address on University Libraries in 1891, it is doubtful if he ever felt much in touch with some phases of modern library methods. He concentrated his attention more and more upon educational problems, particularly upon those connected with scientific schools in America, and devoted no little time to writing and speaking on the subject. The decade from 1860 to 1870 was a time when the founding of technical and industrial schools was prominently before the public, owing in part to the passage of the Morrill Act of 1862, commonly but erroneously called the Agricultural College Bill. When, therefore, in 1871, he was appointed by the government a commissioner to investigate certain phases of the operation of this measure, he accepted the appointment and travelled extensively, observing, interviewing, corresponding, in order to inform himself thoroughly of the difficulties and limitations of the project. In this case, as in others, he found that the greatest obstacle to the success of the undertaking lay in the scarcity of able and accomplished men as professors in the department of science to which these institutions were devoted.

Dr. Gilman's connection with the Sheffield School opened a larger field for his activity and called into play those gifts of leadership and governance with which he was richly endowed. From 1865 to 1872 the chief responsibility for the direction of the school

rested upon his shoulders and with others he succeeded in obtaining for it increased endowment and in raising it to a higher level of efficiency. The success of his work in this field drew to him the attention of those who were seeking a president for the newly established State University of California, and in 1871 he was called to fill that position, a call which at first he refused, but the next year accepted. In his inaugural address, delivered in Oakland in 1872, he laid down the principles upon which a university should be founded and the plan thus outlined shows how broad and strong the germinal ideas of earlier years were growing. "It is on the faculty" he said, "that the building of a university depends. They give their lives to the work. It is not the site, not the apparatus, nor the halls, nor the library, nor the board of regents, which draws the scholars; it is the body of living teachers, skilled in the specialties, eminent in their calling, loving to teach. Such a body of teachers will make a university anywhere."

The time had not yet come when those educational ideals, which were finding expression in many writings of this period, though nowhere more simply and concretely than in Dr. Gilman's own utterances, were to find realization. The University of California was not to prove the laboratory in which his educational experiment was to be tested. Hedged in by the traditions of the college out of which it had grown, limited in its resources, and possessed of an atmosphere that was not in all ways congenial to the broad university policy that Dr. Gilman desired to inaugurate, the university on the Pacific slope in a measure failed in its response to the call which Dr. Gilman made to it. The scene of his success was not to be the West but the East, and already in December, 1873, the death of Johns Hopkins, a wealthy merchant and member of the Society of Friends of Baltimore, had rendered available that great gift, the largest known to American education up to that time, which provided for the establishment of a new university in the city on the Patapsco.

The founding of the Johns Hopkins University took place at an unusual time and under unusual circumstances. Never, in the history of mankind, had the question of university education been under more careful consideration. As Dr. Gilman once said, "A mere enumeration of the reports, histories, controversial pamphlets

and programmes on collegiate and university education which had been printed within the years 1863–1886, would show an amount of attention, on the part of the foremost men of the time, unequalled in the history of education." But, while elsewhere it was a question of improving existing institutions and methods, in Baltimore it was the inauguration of a new foundation. There were no traditions to throw off, no prejudices to combat, no denominational interests to serve, no established routine to reform. A leader was ready in the prime of his powers and filled with the confidence that makes for success; the means at his disposal, though less than those possessed by many existing colleges, were ample for the initiation of the work, and the gift which was unrestricted by conditions was in the hands of a remarkably able board of trustees in whom "professional distinctions and financial experience were happily combined." It is doubtful if conditions had ever been more favorable than were those which confronted Dr. Gilman when in 1875 he accepted the call to Baltimore, and to few men has it ever been given to test a great ideal under such auspicious circumstances.

For twenty-five years, formative years in the history of the higher education in this country, Dr. Gilman remained at the head of the Johns Hopkins University. Upon both university and hospital his personal character, his high ideals, and his genius for wise and skilful organization have left their permanent impress. I need not repeat here what others have said, with so much insight and understanding, of Dr. Gilman's labors in launching and guiding these famous institutions. *Si monumentum quaeris, circumspice.* During these years, under the direction of others, university standards elsewhere have sought the levels that he sought, have realized to a greater or less degree the ideals which from earliest manhood had shaped his own career. At the age of seventy, he laid down the burden, his chief work in life accomplished, and his contribution made in full measure and running over to the intellectual and moral advancement of mankind.

Next to his greatest attainment as the "true founder of the true American university" is his influence as a public-spirited citizen and scholar, who gave generously of his time, thought, and energy for the promotion of good and useful work in the world. To a

degree not common in this day of selfish interests, he coöperated in scores of undertakings and enterprises that lay outside the legitimate field of his labors. Yet to him there was no boundary line within which his duty lay. His ideal of service was as lofty as his ideal of scholarship, and it penetrated as deeply as the smallest details of his private life. His sense of obligation to the student body that surrounded him, to the community in which he lived, and to the nation of his allegiance was highly and sensitively developed. He became a wise and sympathetic adviser of those who during their life at the University or afterward came to him for help or guidance. Few who sought came away without some suggestive and pertinent comment, often aptly illustrated from his own experience, which had a way of sticking in the mind because born of shrewd insight and offered in kindness and without sting. He was interested in men, not necessarily as scholars but as men, and he was inclined to discourage mere scholarship unaccompanied by practical application in the way of useful product. He liked to see students taking their places in the world of affairs, each filling a place of influence, whether as teacher or business man, lawyer or doctor, organizer or investigator, Boniface or Benedict. He valued success and was at all times impatient of indolence or placid contentment. Many who came under his influence will recall his warning against satisfaction and complacency as the enemies of accomplishment. To him each output was but a stepping-stone to better things. He constantly laid stress upon the minor qualifications which contribute to the effectiveness of human effort. He pleaded for greater attention to thoroughness and accuracy, clearness and precision in style and forms of presentation, care and painstaking in chirography and penmanship. Master himself of a graceful and forcible style, possessed of a neat and readable handwriting, and gifted with the power of selecting felicitous words and phrases, he regretted the tendency among specialists to ignore literary and artistic form and to grow careless, slipshod, and indifferent to the manner of presentation. He drew lessons from manuscripts and proof-sheets, as does the preacher from stones and running brooks, and he pointed many a moral to adorn the tales that he told of the eccentricities of genius and the literary perversities

of lesser men. The day of great things was to him the day of small things also, and he had faith in those who forged their sentences as a "gold beater prepares a setting for pearls."

His interest in the affairs of the community, the state and the nation was that of a willing and service-loving citizen. Baltimore's debt to him is deep and lasting. He helped to model her charter, he was a coöperator in her charities and her philanthropies, and was an adviser and more than an adviser in promoting her educational welfare. He was in constant demand for addresses, presentations, and similar functions, both public and private. The Peabody Institute, the Enoch Pratt Free Library, the Samuel Ready Orphan School, the McDonogh School, the Mercantile Library, the Municipal Art Society, the Reform Leagues in city and state, the Charity Organization Society, and the public schools, all to a greater or less extent, received impulse or profit from his coöperation, and no movement for good in the city and state failed to enlist his attention or his services.

That which was true of city and state was also true of the nation. At one time or another he was president of the American Bible Society, of the Slater Fund to educate the Freedmen, of the National Civil Service Reform League, and of the American Social Science Association; he was vice-president of the Peabody Southern Education Fund, a member of the Board of Visitors of the Naval Academy, a trustee of the General Board to promote Education throughout the Union and of the Russell Sage Foundation, and a member of the Venezuelan Boundary Commission. He held these positions not as offices of honor but as offices of trust, involving frequent attendance, extensive travel, and wide correspondence.

In the world of scholarship as in the world of education and philanthropy he was equally versatile and widely interested. For thirteen years he served as president of the American Oriental Society, was a corresponding member of the British Association and the Massachusetts Historical Society, and a member of many other societies of an historical or scientific character. Most important of all, he became the first president of the Carnegie Institution of Washington founded for the promotion of scholarship and research.

These varied connections were but the outward manifestations

of a remarkably alert and inquisitive mind. Probably few equalled him in the ability to grasp the essentials of a scientific or social movement or of appreciating its deeper significance from the standpoint of human progress. He deemed it to be his duty as well as pleasure to understand with something more than a merely superficial comprehension the recent advances in all branches of human activity. He was not merely a wide reader, but he was also a keen and sagacious inquirer, seeking knowledge for its own sake, and using it to meet the demands which the world made upon him. Whether he were addressing a geographical society, a graduating class at the Naval Academy, or a Chamber of Commerce, he drew from his stores of information facts pertinent to the occasion and conclusions suggestive even to those who saw more deeply into their specialties but not more widely the bearing of these specialties on the world at large. He made no pretensions to specialized knowledge, though in some subjects, chiefly those of an historical and a biographical character, he was deeply versed, and the writings that bear his name, either as author or editor, number at least half a dozen volumes.

He was no lover of controversy. He saw in it only a grievous intellectual waste. His kindly and sympathetic nature was opposed to warfare of any kind and his faith in the value of coöperation led him to regret the expenditure of time and energy in acrimonious debate. He took no part in the conflict between science and religion, believing that the influence of research on the whole was favorable to the growth of spiritual life and that faith with all its fluctuations was as permanently operative in human thought as was knowledge. Regarding the comparative claims of literature and science, he would avoid the issue by employing both these forces in alliance for the promotion of intellectual and moral culture. His attitude toward all subjects was synthetic; he would build up and not destroy, and he saw in the world of intellect and applied knowledge, as in the world of university and hospital, one common purpose to which all efforts were contributing and should contribute. The common good was ever present to his mind, and as he wished the University to receive the hearty and enthusiastic support of a faculty of many interests and many minds, so he wished the higher end

for which all universities labored, the cause of civilization, to receive the same undivided support from all who were lovers of a common humanity. Such was the sum of Dr. Gilman's philosophy.

Of the peaceful days which preceded the end of this life of service and blessing we have been given a beautiful picture. "I left him," says a friend, "last August in a lovely garden on the shores of Lake Thun, with beautiful flowers about him, with sweet music in his ears, and with the wonderful panorama of the Alps spread out before his eyes. He was looking back upon a pleasant journey and forward to some weeks of rest in this peaceful place. His work was over and well done, he was free from care and pain, his mind was clear and bright, and the evening of his life was unclouded and serene. He came home some weeks afterward, and then died in an instant without suffering, leaving behind him no memories which any friend would wish to change." The circuit of his life found singular completeness in his death. Among the kinsmen who loved him and the townsfolk who admired and revered him, he passed away in the home of his fathers, whence he had gone out more than sixty years before.

CHARLES M. ANDREWS.

JOHNS HOPKINS UNIVERSITY.

JOSEPH WHARTON, Sc.D., LL.D.

(Read November 5, 1909.)

The unceasing activity of Joseph Wharton's career of eighty-two years came to a close on January 11, 1909, and at that period so much was written on his personal character and business achievements that, for the records of The Philosophical Society, it seems desirable to dwell more exclusively on the intellectual side of his striking personality.

In men like the immortal founder of this Society—like Jefferson and Morse and Edison—there is a many-sidedness that makes for physical success in life, as well as for attainment in those branches of learning which commonly yield but little gain to their professors. The shrewdness of a man of affairs, able to shift for himself, quick at seizing opportunities of profit and learned in the free-masonry of trade, is mingled in such rare examples with those qualities of mind which make for academic contemplation and the power to assimilate knowledge, use it, and give it forth in clear and convincing utterance.

There may be points of contrast in the two dissimilar human species, but we usually associate distinct personal traits with each. The professor is a sedentary person, who makes his somewhat meagre living by devotion to the library, and meditative pursuits; the man of business is an active spirit whose busy life affords no time for picking up useful knowledge. These two opposing orders of men have so little in common that it is a source of wonder when their qualities unite in a single individual. He is a marked man who is blessed with such many-sidedness, and he has invariably become a leader amongst his kind.

And such, in his degree, was Joseph Wharton. To use a phrase of trade, his "business head" was marvellous. His keen eye seemed to see physically just what events would flow from given causes. He could apparently look through an entanglement of

existing affairs and coördinate their results with unerring foresight. He knew every in-and-out of technical business. He rarely received a legal paper for execution in which he could not lay his finger on some blemish that would ultimately work detriment, and he had some vast treasury of knowledge on all the forms for possessing and passing real estate, upon which he could draw with faultless memory. His command of the methods of finance was perfect. He was by instinct a banker; and he would have been a memorable Secretary of the Treasury, had he allowed his friends to put forth the effort which alone was needed to elevate him to that office. He knew how to act with deadly swiftness, and he knew how to wait—both trading capacities of the highest order.

When, to these purely business talents, was added his technical insight, there came forth a combination which in the realm of commerce was nearly irresistible. He knew chemistry and metals, not wholly by laborious teaching in the technical school, but by that instinct for driving nature to do his will which was a life-long aim. Hence he was equipped with one ingredient when the other was wanted, and it is the destiny of such natures to find the other. The man who goes fishing without a hook ought not to complain if the man with the hook catches the fish. To be up and ready is the watch-word of such success, and up very early and ready very eagerly Joseph Wharton always was.

Thus, he found a way to make zinc in Bethlehem, Pa., before it was made elsewhere in the United States, and thus he was the pioneer in the mining and manufacture of nickel in this country.

But, if the knowledge of chemistry and metallurgy ran smoothly into the cogs of business, it also denoted that wiser and nobler side of the mind of Joseph Wharton which threw upon the details of a life of trade the radiance of learning; the reflection from that finer wisdom which is not in the service of self, but exists for the bettering of mankind, who are kin. His instincts for affairs, for commerce and the exchange of commodities, were indeed a phase of that recognition of the orderly fabric of the universe which gifted him with insight into her functions.

But he was of that larger nature which does not stop at self, and he went on from the level of personal accretion to that higher

level of genuine usefulness by the impulse in him toward those intellectual pursuits which ordinarily monopolize the powers of their possessor. He might be likened to an Atalanta who stopped to pick up the golden balls so temptingly dropped on the course, who gathered them all in safely and prudently and then, besides, won the race. And the goal was not a mere contest of strength or endurance, but an intellectual prize in which the victor came forth a benefactor to his kind, both in giving and in knowledge, and a benefit to himself in the resources of a full mind.

The very lack of academic education serves to measure the native richness of Joseph Wharton's mind. He had little schooling and yet, as he grew old in experience and reading, he was more than half a scholar. He had so large a miscellaneous store of facts in his ample head that he could generalize wisely on many subjects. This often gave his views the appearance of more exact scholarship than he possessed. He knew chemistry as a practical user, rather than as a student; and yet he was appointed one year to the chair of the Visiting Committee on Chemistry to Harvard College, a compliment he never forgot and always quoted with extreme satisfaction. Indeed, he meant to recognize the distinction by a liberal endowment, but this was one of the plans which went over the border with his eager spirit.

If he felt the lack of some scholarly attainments, it was rather because he disliked to be unpossessed of any branch of culture, than because he needed them to complete his already rare equipment. It was an early and life-long ideal of his to master mathematics.

When the Civil War broke out he, as a non-combatant by conviction, decided to turn all his possessions into ready securities, buy a good stout horse and a wagon large enough for his family, and drive with his needed impedimenta to Harvard College. There, in academic peace, he would take a course in the higher mathematics and perfect himself technically in those sciences which he afterwards came to know by observation and by reading.

He was capably furnished with the elements of geology and astronomy, and he was inquisitive in every other physicial science, but his knowledge of botany and ornithology was not so wide. I have known him to ride post-haste from Jamestown, R. I., to Pro-

fessor Agassiz's distant house in Newport with an uncommon species of marine life for investigation, and his interest in the land crabs of Cuba and the minor animals of the West was great; but his mind ran rather to the larger cosmic sciences, because it was of large mould, and was used to push ahead into speculative paths.

He lectured more than once on the moon and the Alps and glaciers, and his overflowing store of facts came forth fluently and without special preparation. He made a small but select collection of such minerals as appealed to him from the industrial as well as the scientific side; and he had gathered about him some preserved specimens of curious animal life—and be it said to his great credit as a humane lover of nature, he was insistent that no animal or bird on property belonging to him should be wantonly killed. I have heard him repeat again and again that he liked the wild things let alone in their native lairs.

His most intimate taste was for gems, rather as natural phenomena than from intrinsic worth; and his keenness in this field is fully illustrated by an episode at a dinner table where many guests passed around a great emerald belonging to one of the ladies. When it came to Mr. Wharton, there was a pause as he was asked what he thought of it. He said, with unflinching honesty, "It would be of immense value if it were genuine."

His own collection of gems was not at all exhaustive, but it had been made with discrimination and he loved to go over the stones with some congenial hearer and give forth rare funds of interesting data concerning each stone or species.

But the speculative side of science was, as I have said, more to his liking than the exact. He was a sort of discoverer garbed in the limiting drab of Friendly convention. If his spirit ever existed before, it must have inhabited the body of a Cortez or a Cabot. He was always seeking the ultimate; never satisfied to rest. He would quote with deep feeling the lines of Tennyson on "Ulysses":

"It little profits that an idle king
By this still hearth, among these barren crags,
Matched with an aged wife, I mete and dole
Unequal laws unto a savage race,
That hoard and sleep and feed, and know not me.
I cannot rest from travel, I will drink
Life to the lees:"

and he was enamored with the career of Cortez in Mexico. The field of his endeavor happened to lie in storing, not discovering gold, and his pursuits were peaceful; but the mind that kept on the frontier of knowledge and used the instruments of nature and business to conquer its purposes, was necessarily a mind given to speculative thought. He was not an inductive thinker, he did not pass from the small to the great by laborious stages; he liked to reach out into the unknown and shape his destiny with the light he could snatch.

So it was that economics employed much of his leisure. His dual quality led him to see from the business platform the uses of the tariff in building up the private fortune as well as the national wealth and independence. He was an ardent advocate of the theories of his friend Carey; but he was much more, he was a practical worker in the tariff toil. He formed one tariff almost single-handed, and had a hand in many others. He fought for the principle valiantly in speech and in print; but he also worked behind the guns. His speculative talents supported his "business head" and he demonstrated in this, as in all his other enterprises, the truth of the axiom that "knowledge is power."

It was the perception of this old but too often ignored principle that led him to suggest and endow The Wharton School of Finance and Commerce. He knew, as few nowadays do, the intellectual hiatus in the business life; and he thought that this form of inoculation might introduce the essence of technical knowledge, along with the humanities, into the one-sided development of the prevailing young business man. He was a good deal disappointed in his expectations, perhaps because the teacher of such courses is necessarily a theorist; but his example has been followed in other colleges and in other lands, and his principle was a genuine one that it was wise to exploit.

Then, too, his bias for speculative analysis, as well as his sturdy independence of thought, was shown in his knowledge of the Bible, and of the wide literature which modern criticism has produced in exploration of its origins. He spoke German and French familiarly, and these two forces had been made to serve in both his business and his intellectual advancement; but he "had little Latin

and less Greek" and no Hebrew. I think his onward spirit meant to live always, and in some tranquil time-to-be, he was going to acquire these useful aids to his mastery of Biblical research.

He had, early, a distinct talent for drawing with characteristic preciseness and he produced a medal or two and carved an intaglio which showed fidelity to line rather than breadth of view; and he later wrote verse with facility and sentiment. But he had, as Franklin had, and all men of his frugal stamp, but little taste in æsthetics, saving when they applied to the bolder treatment of nature in landscape gardening, or rather to the good sense of leaving natural landscape as near its own forms as is consistent with human comfort. He had but limited ear for music; although he would sing with hearty exuberance; but he had amazing wit and humor and some of his droll stories or poems are enduringly funny.

Such, briefly, was Joseph Wharton. His life was one of physical and mental action, and such lives make lasting biographies. Only one of his versatile characteristics has been dwelt on here, and the record in mere outline has already overpassed the limit. As he stood, a manly figure, at the threshold of our new business and intellectual life, as he was a leading figure in the formation of the new navy which so easily dispatched Spain, as he invented new avenues of manufacture and a form of education not before tried, as he helped to cast the shield of protection over industries undeveloped by reason of too little self-respect—he is a man marked out as an example and a guide for oncoming men, and the record of his many useful years should one day be made to endure in the pages of a fitting biography.

HARRISON S. MORRIS.

MINUTES.

MINUTES.

Stated Meeting January 1, 1909.

Mr. J. G. Rosengarten in the Chair.

The decease was announced of Dr. Richard A. F. Penrose at Philadelphia, on December 26, 1908, aged 81.

Mr. R. H. Mathews, of Paramatta, N. S. Wales, presented a paper on "Ceremonial Stones used by the Australian Aborigines."

The Judges of the Annual Election of Officers and Councillors held on this day, between the hours of two and five in the afternoon, reported that the following named persons were elected, according to the laws, regulations and ordinances of the Society, to be the officers for the ensuing year.

President:

William W. Keen.

Vice-Presidents:

William B. Scott, Simon Newcomb, Albert A. Michelson.

Secretaries:

I. Minis Hays, James W. Holland,
Arthur W. Goodspeed, Amos P. Brown.

Curators:

Charles L. Doolittle, William P. Wilson, Leslie W. Miller.

Treasurer:

Henry La Barre Jayne.

Councillors:

(*To serve for three years.*)

Charlemagne Tower, William Gilson Farlow,
Robert S. Woodward, R. A. F. Penrose, Jr.

Special Meeting January 9, 1909.

WILLIAM W. KEEN, LL.D., President, in the Chair.

Professor J. P. Mahaffy, of Trinity College, Dublin, read a paper on "The Irish Race."

Stated Meeting January 15, 1909.

WILLIAM W. KEEN, LL.D., President, in the Chair.

Dr. Barton C. Hirst read an obituary notice of Dr. R. A. F. Penrose. (See page *lviii.*)

The decease was announced of the following members:

Prof. George E. Hough, at Evanston, Ill., on January 1, 1909, æt. 72.

Mr. Joseph Wharton, at Philadelphia, on January 11, 1909, æt. 82.

The following papers were read:

"Some Aspects of the Question of English Speaking," by Prof. J. W. Bright. (Introduced by Dr. W. W. Keen.) Discussed by Prof. Schelling, Prof. Learned and Dr. Keen.

"The Solgram System of Color Photography," by Mr. W. C. South. (Introduced by Dr. W. W. Keen.)

Stated Meeting February 5, 1909.

WILLIAM W. KEEN, LL.D., President, in the Chair.

An invitation was received from the New York Academy of Sciences to attend its Darwin Centenary Commemoration on February 12. Prof. Henry Kraemer, President Henry S. Pritchett and Prof. E. G. Conklin, were appointed to represent the Society on the occasion.

The decease was announced of Mr. Charles Platt, at Philadelphia, on January 23, 1909, aged 80.

Prof. E. G. Conklin offered a minute in commemoration of the centenary of the birth of Charles Darwin (see page *lvi*) which was unanimously adopted.

Prof. Maurice Bloomfield read a paper on "The Hindu Idea," which was discussed by Prof. Jastrow.

Stated Meeting February 19, 1909.

William W. Keen, LL.D., President, in the Chair.

Prof. Charles M. Andrews, of Johns Hopkins University, presented an obituary notice of President Daniel C. Gillman. (Communicated by Dr. W. W. Keen.) (See page *lxii.*)

The decease was announced of Mr. Robert Patterson, at Blacksburg, Va., on February 14, 1909, æt. 90.

Mr. Frederick H. Newell, director of the U. S. Reclamation Service, introduced by the President, presented a paper on "The Conservation of Water Resources in the Western United States."

Special Meeting March 3, 1909.

William W. Keen, LL.D., President, in the Chair.

Hon. Charlemagne Tower read a paper on "Diplomatic Life and Diplomatic Usage."

Stated Meeting March 5, 1909.

William W. Keen, LL.D., President, in the Chair.

The decease was announced of the following members:

Prof. Guillaume Lambert, at Brussels, on February 22, 1909, aged 92.

Prof. James W. Moore, M.D., at Easton, Pa., on February 28, 1909, æt. 64.

Mr. William R. Blair, director of the Research Observatory of the U. S. Weather Bureau, introduced by the President, read a paper on "The Exploration of the Upper Air by means of Kites and Balloons." (See page 25.) Discussed by Mr. Lehman and Mr. Goodwin.

Stated Meeting March 19, 1909.

William W. Keen, LL.D., President, in the Chair.

The decease was announced of Prof. Martin Hans Boyé, at Coopersburg, Pa., on March 5, 1909, aged 97.

The following papers were read:

"On Coal Tar Products and their Application in the Arts and

Medicine," by Prof. Marston T. Bogert, introduced by the President, which was discussed by Prof. Keller, Mr. Du Bois, Dr. Holland, Prof. Kraemer and Prof. Bogert.

"Recent Surgical Progress," by Dr. W. W. Keen.

Stated Meeting April 2, 1909.

WILLIAM W. KEEN, LL.D., President, in the Chair.

The decease was announced of Dr. William Henry Wahl, at Philadelphia, on March 23, 1909, æt. 60.

Prof. A. V. Williams Jackson, of Columbia University, introduced by the President, read a paper on "Mithraism and Manichæism—Two Developments of Early Persian Religious Thought." Discussed by Prof. Jastrow.

Stated Meeting April 16, 1909.

I. MINIS HAYS, Secretary, in the Chair.

The disease was announced of Dr. Persifor Frazer, at Philadelphia, on April 7, 1909, aged 65.

General Meeting April 22, 23 and 24, 1909.

Thursday, April 22. Opening Session—2 o'clock.

WILLIAM W. KEEN, LL.D., President, in the Chair.

The following papers were read:

"The American-British Atlantic Fisheries Question," by Thomas William Balch, of Philadelphia.

"The Nation and the Waterways," by Prof. Lewis M. Haupt, of Philadelphia. Discussed by Dr. Cyrus Adler.

"The Evolution of the City of Rome from its Origin to the Gallic Catastrophe," by Prof. Jesse B. Carter, of Rome, Italy. (Communicated by the President.) Discussed by Dr. W. W. Keen.

"Why America Should Reëxplore Wilkes' Land," by Edwin Swift Balch, of Philadelphia. Discussed by Admiral Melville, Mr. H. G. Bryant and Dr. W. W. Keen.

"The Volcanic Formations of Java," by Henry G. Bryant, of Philadelphia.

The following preamble and resolutions were unanimously adopted:

Whereas, The United States in former years made many brilliant discoveries in the Antarctic, including the continent of Antarctica by Charles Wilkes, and

Whereas, The United States has not taken any part in the recent scientific explorations of the South Polar regions, therefore be it

Resolved, That The American Philosophical Society requests the coöperation of the scientific and geographical societies of this country to urge on the Government of the United States that it do make sufficient appropriations to send a vessel, under the direction of the Secretary of the Navy, to thoroughly explore and survey the coast of Wilkes Land, and other parts of Antarctica.

Friday, April 23. Executive Session—10 o'clock.

William W. Keen, LL.D., President, in the Chair.

Prof. Josiah Royce (elected 1908) was admitted into the Society.

The proceedings of the Officers and Council were submitted.

Morning Session—10.05 o'clock.

William W. Keen, LL.D., President, in the Chair.

"The Brains of Two White Philosophers and of Two Obscure Negroes" (illustrated by specimens and diagrams), by Prof. Burt G. Wilder, of Ithaca, N. Y. Discussed by Dr. E. A. Spitzka.

"Some Conditions Modifying the Interpretation of Human Brain Weight Records," by Dr. H. H. Donaldson, of Philadelphia.

"Some Notes on the Modification of Color in Plants," by Prof. Henry Kraemer, of Philadelphia. Discussed by Prof. Harshberger, Prof. Hobbs, Prof. W. T. Hewett and Prof. Kraemer.

"Comparative Leaf Structure of the New Jersey Strand Plants," by Prof. John W. Harshberger, of Philadelphia. Discussed by Prof. Wilder and Mr. Harrison S. Morris.

"The Composition of Chrysocolla," by Prof. Harry F. Keller, of Philadelphia.

"The Chemical Work of the U. S. Geological Survey," by Frank Wigglesworth Clarke, of Washington.

"Recent Work on the Physics of the Ether," by Paul R. Heyl, of Philadelphia. (Introduced by Prof. Harry F. Keller.)

"Effect of Bleaching Powder Upon Bacterial Life in Water," by Prof. William Pitt Mason, M.D., of Troy, N. Y. Discussed by Prof. Kraemer and Dr. W. J. Holland.

"The Detonation of Gun Cotton," by Prof. Charles E. Munroe, of Washington.

On motion it was ordered that a telegram conveying the Society's good wishes and great regret at his absence from the meeting be sent to Prof. Simon Newcomb. To this telegram a reply was received from Prof. Newcomb thanking the Society for its kind greetings which he highly appreciated.

Afternoon Session—2.30 o'clock.

William B. Scott, LL.D., Vice-President, in the Chair.

"South American Fossil Cetacea," by Dr. Frederick W. True, of Washington. Discussed by Prof. W. B. Scott.

"The Destruction of the Fresh Water Fauna of Western Pennsylvania," by Dr. Arnold E. Ortman, of Pittsburgh.

"The Stratigraphic Position of the Oolitic Iron-Ore at Bloomsburg, Pa.," by Gilbert van Ingen, of Princeton. (Introduced by Prof. W. B. Scott.)

Albert A. Michelson, LL.D., Vice-President, in the Chair.

"Machines and Engineering in the Renaissance and in Classical Antiquity," by Prof. Christian Hülsen, of Rome Italy. (Introduced by Dr. W. W. Keen.)

"On the Extent and Number of the Indo-European Peoples," by Prof. Maurice Bloomfield, of Baltimore.

"A Mechanical Device for the Tabulation of the Sums of Numerous Variable Functions," by Prof. Ernest W. Brown, of New Haven.

"The Burning Bush and the Origin of Judaism," by Prof. Paul Haupt, of Baltimore.

"On Certain Generalizations of the Problem of Three Bodies," by President Edgar Odell Lovett, of Houston, Texas.

"Penrose's Graphical Method for Orbit Determination," by Prof. Eric Doolittle, of Flower Observatory, Philadelphia.

Evening Session.

William W. Keen, LL.D., President, in the Chair.

Commemoration of the Centenary of Charles Darwin's Birth (February 12, 1809) and the Fiftieth Anniversary of the Publication of the "Origin of Species" (November 24, 1859).

The following addresses were delivered:

"Personal Reminiscences of Charles Darwin and of the Reception of the '*Origin of Species.*'" by His Excellency, the Right Honorable James Bryce, British Ambassador at Washington.

"The Influence of Darwin on Natural Science," by Prof. George Lincoln Goodale, of Cambridge.

"The Influence of Darwin on the Mental and Moral Sciences," by Prof. George Stuart Fullerton, of New York.

Attention was called to the fact that there were two members of the Society still living who were friends and colaborers of Charles Darwin—Sir Joseph Dalton Hooker and Dr. Alfred Russell Wallace, and it was ordered that on the occasion of this Commemoration the Society transmit by cable to them its greetings and congratulations on the general acceptance of the views in the elaboration and promulgation of which they took an active and effective part.

Saturday, April 24. Executive Session—10 o'clock.

Albert A. Michelson, LL.D., Vice-President, in the Chair.

Candidates for membership were balloted for, and the tellers reported the election of the following:

Residents of the United States.

Louis A. Bauer, Ph.D. (Berlin), Washington, D. C.

Marston Taylor Bogert, New York City.

Hermon Carey Bumpus, Ph.D., New York City.

Alexis Carrel, M.D., New York City.

Edwin Brant Frost, Williams Bay, Wis.
Robert Almer Harper, Ph.D., Madison, Wis.
William Herbert Hobbs, Ph.D., Ann Arbor, Mich.
A. V. Williams Jackson, Ph.D., LL.D., Yonkers, N. Y.
John Frederick Lewis, Philadelphia.
Abbott Lawrence Lowell, Boston, Mass.
William Romaine Newbold, Ph.D., Philadelphia.
Charles Bingham Penrose, M.D., Ph.D., Philadelphia.
William Howard Taft, Washington.
Charles Richard Van Hise, M.S., LL.D., Madison, Wis.
Victor Clarence Vaughan, M.D., Sc.D., LL.D., Ann Arbor, Mich.

Foreign Residents.

Francis Darwin, M.A., F.R.S., Cambridge, Eng.
Hermann Diels, Ph.D., Berlin.
Emil Fischer, Ph.D., M.D., Berlin.
Friedrich Kohlrausch, Ph.D., Marburg.
Wilhelm Pfeffer, Ph.D., Leipzig.

Morning Session.

ALBERT A. MICHELSON, LL.D., Vice-President, in the Chair.

Prof. Robert William Wood (elected 1908) and Dr. Louis A. Bauer, a newly elected member, were admitted into the Society.

The following papers were read:

"On the Remarkable Changes in the Tail of Comet C. 1908 (Morehouse), and On a Theory to Account for these Changes," by Prof. E. E. Barnard, of Yerkes Observatory, Williams Bay, Wis. Discussed by Prof. M. B. Snyder, Prof. Michelson, Dr. George F. Becker and Prof. Ernest W. Brown.

"The Past History of the Earth as Inferred from the Mode of Formation of the Solar System," by Dr. T. J. J. See, of U. S. Naval Observatory, Mare Island, Cal.

"The Linear Resistance between Parallel Conducting Cylinders," by Prof. A. E. Kennelly, of Cambridge.

"Vacuum Effects in Electrical Discharge around a Right Angle in a Wire," by Prof. Francis E. Nipher, of St. Louis.

"The Ruling of Diffraction Gratings," by Prof. Albert A. Mich-

elson, of Chicago. Discussed by Prof. Robert W. Wood, Prof. M. B. Snyder and Prof. Doolittle.

"On an Adjustment for a Plane Grating similar to Rowland's for the Concave Grating," by Prof. Carl Barus, assisted by M. Barus, of Providence.

"The Electron Method of Standardizing the Coronas of Cloudy Condensation," by Prof. Carl Barus, of Providence.

"The Electrometric Measurements of the Potential Difference between two Conductors of a Condenser containing a highly Ionized Medium," by Prof. Carl Barus, of Providence.

"Solar Activity and Terrestrial Magnetic Disturbances," by Dr. L. A. Bauer, of Washington. Discussed by Prof. Kennelly and Dr. Bauer.

"The Effect of Temperature on the Absorption Spectra of Certain Solutions," by Prof. Harry C. Jones, of Baltimore. (Introduced by President Ira Remsen.)

"The Specific Chemo-Therapy of the Protozoal Diseases," by Dr. Simon Flexner, of the Rockefeller Institute for Medical Research, New York.

"The Unsuspected Presence of Habit-Forming Agents in Beverages and Medicines," by Dr. Lyman F. Kebler, of Washington. (Introduced by Dr. Harvey W. Wiley.) Discussed by Dr. E. A. Spitzka and Dr. Kebler.

Afternoon Session—2.30 o'clock.

William B. Scott, LL.D., Vice-President, in the Chair.

Prof. William Herbert Hobbs and Mr. Abbott Lawrence Lowell, newly elected members, were admitted into the Society.

The following papers were read:

Symposium on Earthquakes.

"Introduction—Classification—Discussion of Volcanic Earthquakes—Description, with illustrations, of the Charleston, S. C., and Kingston, Jamaica, Disasters," by Prof. Edmund O. Hovey, of New York. (Introduced by Prof. W. B. Scott.)

"The Present Status and the Outlook of Seismic Geology," by Prof. William H. Hobbs, of Ann Arbor, Mich.

"Conditions Leading to Tectonic Earthquakes—Instruments used in the Study of Earthquakes—Suggestions for a National Seismological Bureau," by Prof. Harry F. Reid, of Baltimore. (Introduced by Prof. W. B. Scott.)

These three papers were discussed by Profs. Michelson, William Morris Davis, W. H. Hobbs, H. F. Reid and W. B. Scott.

The following preamble and resolutions were presented and unanimously adopted:

Whereas, Earthquakes have been the cause of great loss of life and property within the territory of the United States and its possessions, as well as in other countries, and

Whereas, It is only through the scientific investigation of the phenomena that there is hope of discovering the laws which govern them, so as to predict their occurrence and to reduce the danger to life and property, and

Whereas, Such investigations can be successfully conducted only with the support of the general government, be it, therefore,

Resolved, That this Society urge upon Congress the establishment of a National Bureau of Seismology, and suggest that this bureau be organized under the Smithsonian Institution with the active coöperation of the other scientific departments of the government and that this bureau be charged with the following duties:

(*a*) The collection of seismological data.

(*b*) The establishment of observing stations.

(*c*) The organization of an expeditionary corps for the investigation of special earthquakes and volcanic eruptions in any part of the world.

(*d*) The study and investigation of special earthquake regions within the National domain. And

Resolved, That copies of these resolutions be transmitted to the President, to the President of the Senate, to the Speaker of the House of Representatives, and to the Secretary of the Smithsonian Institution.

Stated Meeting May 7, 1909.

WILLIAM W. KEEN, LL.D., President, in the Chair.

Dr. Charles B. Penrose, Mr. John Frederick Lewis and Prof. William Romaine Newbold, newly elected members, were admitted into the Society.

Letters accepting membership were read from:

Louis A. Bauer, Ph.D. (Berlin), Washington, D. C.

Marston Taylor Bogert, New York.

Hermon Carey Bumpus, Ph.D., New York City.

Alexis Carrel, M.D., New York City.

Edwin Brant Frost, Williams Bay, Wis.

A. V. Williams Jackson, Ph.D., LL.D., Yonkers, N. Y.

John Frederick Lewis, Philadelphia.

William Romaine Newbold, Ph.D., Philadelphia.

Charles Bingham Penrose, M.D., Ph.D., Philadelphia.

William Howard Taft, Washington.

Charles Richard Van Hise, M.S., LL.D., Madison, Wis.

Victor Clarence Vaughan, M.D., Sc.D., LL.D., Ann Arbor, Mich.

A letter was received from Dr. Alfred Russell Wallace, thanking the Society for its kind greetings sent when celebrating Darwin's centenary. (See page ix.)

The decease was announced of Mr. Andrew Mason, at New York, on April 28, 1909, aged 80.

Dr. Alexander Graham Bell read a paper on "Aërial Locomotion," which was discussed by Mr. A. E. Lehman and Prof. M. B. Snyder.

Stated Meeting May 21, 1909.

Mr. H. LA BARRE JAYNE, Treasurer, in the Chair.

Letters accepting membership were read from:

Francis Darwin, M.A., F.R.S., Cambridge, Eng.

Hermann Diels, Ph.D., Berlin.

Emil Fischer, Ph.D., M.D., Berlin.

Friedrich Kohlrausch, Ph.D., Marburg.

Wilhelm Pfeffer, Ph.D., Leipzig.

A letter was received from Sir Joseph Dalton Hooker expressing

his thanks for the Society's greeting conveyed by cablegram on the occasion of the commemoration of the centenary of Charles Darwin. (See page ix.)

An invitation was read from the Massachusetts Institute of Technology inviting the Society to be represented at the inauguration of Dr. Richard C. Maclaurin as President, on June 7. On motion the President was authorized to appoint such a representative.

The decease was announced of Dr. C. Newlin Peirce, at Philadelphia, on May 16, 1909, aged 80.

Mr. R. H. Mathews read a paper on "Some Burial Customs of the Australian Aborigines."

D. Reed and Albert H. Wright. (Communicated by Prof. Burt G. Wilder.)

"Further Notes on Ceremonial Stones, Australia," by R. H. Mathews.

Stated Meeting, October 15, 1909.

William W. Keen, M.D., LL.D., President, in the Chair.

The decease was announced of Prof. Otto Donner, at Helsingfors, on September 17, 1909.

Dr. Randle C. Rosenberger read a paper on "Typhoid Carriers."

Stated Meeting, November 5, 1909.

William W. Keen, M.D., LL.D., President, in the Chair.

Invitations were received:

From the College of Physicians of Philadelphia, inviting the Society to be represented at the dedication of its New Hall.

From the XVIIth International Congress of Americanists to be represented at the Congress to be held first at Buenos Aires from May 16 to 21, 1910, and then in the City of Mexico in the following September.

The decease was announced of:

Henry Charles Lea, LL.D., at Philadelphia, on October 24, 1909, æt. 84.

Hon. William Butler, at West Chester, Pa., on November 3, 1909, æt. 87.

Mr. Harrison S. Morris read an obituary notice of Mr. Joseph Wharton.

Dr. W. B. Cannon read a paper on "The Correlation of the Gastric and Intestinal Digestive Processes and the Influence of Emotions upon Them."

Mr. John C. Willis, Director of the Royal Botanic Garden, Colombo, read a paper on "The Vegetation of Ceylon."

Stated Meeting, November 19, 1909.

William W. Keen, M.D., LL.D., President, in the Chair.

Prof. C. L. Doolittle read a paper on "Halley's Comet."

Prof. Edward C. Pickering was elected a Vice-President to fill the unexpired term of the late Prof. Simon Newcomb.

Stated Meeting, December 3, 1909.

William W. Keen, M.D., LL.D., President, in the Chair.

An invitation was received from the president of the Eighth International Zoological Congress to send delegates to the Congress to be held at Graz, Austria, from August 15 to 20, 1910.

Prof. E. P. Cheyney read a paper on "The Court of Star Chamber in the Time of Queen Elizabeth and the Early Stuarts."

Stated Meeting, December 17, 1909.

William W. Keen, M.D., LL.D., President, in the Chair.

The decease was announced of M. Serge Nikitin, at St. Petersburg, on November 18, 1909.

The Annual Address of the President was delivered by Dr. William W. Keen.

Dr. Edward Meyer, of Berlin, read a paper entitled "The Story of the Wise Ahikar."

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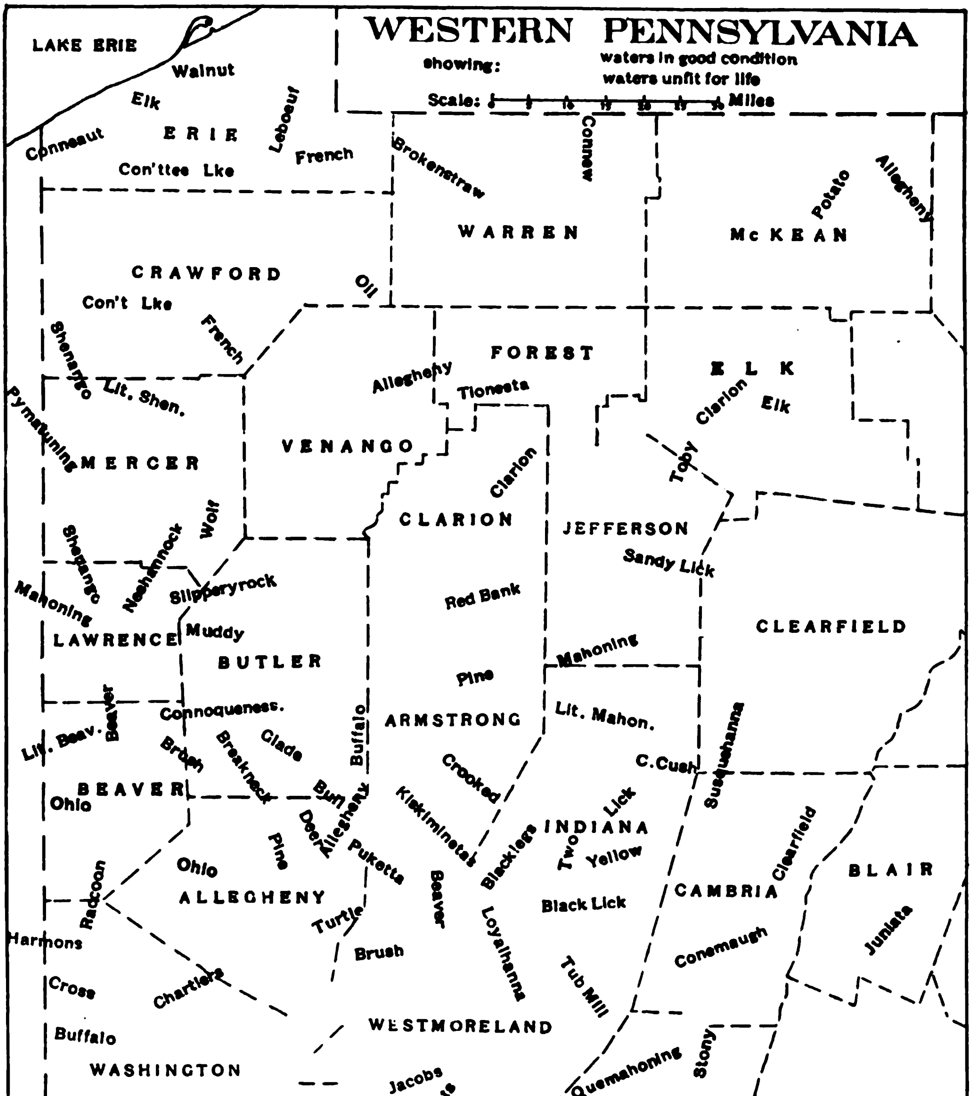
WESTERN PENNSYLVANIA
showing:
waters in good condition
waters unfit for life
Scale:
Miles
LAKE ERIE
Walnut
Elk
ERIE
Conneaut
Leboeuf
French
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Brokenstraw
Conew
WARREN
Potato
Allegheny
McKEAN
CRAWFORD
Con't Lke
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JEFFERSON
Shenango
Neshannock
Wolf
Mahoning
Slipperyrock
Sandy Lick
LAWRENCE
Muddy
BUTLER
Red Bank
CLEARFIELD
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Deer
Allegheny
INDIANA
Pine
Two
Yellow
Puketta
Blacklegs
Clearfield
BLAIR
Ohio
Raccoon
ALLEGHENY
Beaver
CAMBRIA
Black Lick
Turtle
Loyalhanna
Harmons
Brush
Conemaugh
Juniata
Tub Mill
Cross
Chartiers
WESTMORELAND
Buffalo
Stony
Quemahoning
WASHINGTON
Jacobs
Mounts
Youghiogheny
Indian
Redstone
BEDFORD
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SOMERSET
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Casselman
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1910

THE AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA, FOR PROMOTING USEFUL KNOWLEDGE

ANNOUNCES THAT IN

DECEMBER, 1910

IT WILL AWARD ITS

MAGELLANIC GOLD MEDAL

TO THE AUTHOR OF THE BEST DISCOVERY, OR MOST USEFUL INVENTION, RELATING TO NAVIGATION, ASTRONOMY, OR NATURAL PHILOSOPHY (MERE NATURAL HISTORY ONLY EXCEPTED) UNDER THE FOLLOWING CONDITIONS :

1. The candidate shall, on or before November 1, 1910, deliver free of postage or other charges, his discovery, invention or improvement, addressed to the President of the American Philosophical Society, No. 104 South Fifth Street, Philadelphia, U. S. A., and shall distinguish his performance by some motto, device, or other signature. With his discovery, invention, or improvement, he shall also send a sealed letter containing the same motto, device, or other signature, and subscribed with the real name and place of residence of the author.

2. Persons of any nation, sect or denomination whatever, shall be admitted as candidates for this premium.

3. No discovery, invention or improvement shall be entitled to this premium which hath been already published, or for which the author hath been publicly rewarded elsewhere.

4. The candidate shall communicate his discovery, invention or improvement, either in the English, French, German, or Latin language.

5. A full account of the crowned subject shall be published by the Society, as soon as may be after the adjudication, either in a separate publication, or in the next succeeding volume of their Transactions, or in both.

6. The premium shall consist of an oval plate of solid standard gold of the value of ten guineas, suitably inscribed, with the seal of the Society annexed to the medal by a ribbon.

All correspondence in relation hereto should be addressed

TO THE SECRETARIES OF THE

AMERICAN PHILOSOPHICAL SOCIETY

No. 104 SOUTH FIFTH STREET

PHILADELPHIA, U. S. A.

PROCEEDINGS

OF THE

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HELD AT PHILADELPHIA

FOR PROMOTING USEFUL KNOWLEDGE

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